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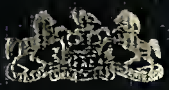

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PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES
BULLETIN G 19

THE DEVONIAN OF PENNSYLVANIA

MIDDLE AND UPPER DEVONIAN

By
BRADFORD WILLARD

KEYSER LIMESTONE AND HELDERBERG GROUP

By Frank M. Swartz

ORISKANY GROUP

By Arthur B. Cleaves

Department of Internal Affairs
William S. Livengood, Jr., *Secretary*

Topographic and Geologic Survey
George H. Ashley, *State Geologist*

Harrisburg, Pa.
1939

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HARRISBURG, PA.

LETTER OF TRANSMITTAL

Secretary of Internal Affairs,
Department of Internal Affairs,
Harrisburg, Pennsylvania.

Dear Sir:

I have the honor to present herewith and to recommend the publication of a volume on the Devonian rocks of Pennsylvania. Of the twelve rock systems present in Pennsylvania, it is by all odds the largest, both in volume and thickness of rocks, and, next to the Pennsylvanian, which contains the Coal Measures, is largest in exposed surface and in the value of mineral products that rocks of this age have yielded. Devonian rocks have yielded most of the oil and gas found in Pennsylvania, most of the glass sand which has made our glass industry the greatest in the world, limestone for building, flagstone, fine sand for many uses, silica clays, some iron ore and other minor products.

From the scientific side the Devonian is perhaps more completely developed and in greater thickness in Pennsylvania than anywhere else in the world, having a maximum thickness of 10,000 feet or more and representing an original body of sediments of probably not less than 50,000 and possibly 60,000 cubic miles of rock in Pennsylvania alone, a larger body than probably exists in any similar area in the world.

The present study represents many years of work, all three of the authors having spent a few to many years in a study of the subject before being asked to join the Survey. The sections on the Oriskany by Dr. Arthur B. Cleaves, and on the Helderberg by Dr. Frank M. Swartz, are condensed reports covering highly detailed studies of those two groups of rocks upon which more detailed reports will be presented later. Each of these groups represents rocks having a thickness of only a few hundred feet and their outcrops have been traced, mapped and studied along the hundreds of miles through which they crop out in Pennsylvania.

The rest of the report by Dr. Bradford Willard covers thousands of feet of sediments of the Middle and Upper Devonian. The Second Geological Survey subdivided these rocks into two formations. In the present report they are divided into nine groups, each of which is divided into two or more formations, and these in turn into a large number of identified and described members or strata. It is anticipated that this report will find interested readers among geologists all over the world, for the Devonian is one of the major divisions of earth history, its rocks are world wide, and this report will, I believe, for many years be a standard text book for the American Devonian.

Finally, I want to express my appreciation to the three authors of this report for the fine work they have done.

Respectfully submitted,

L302083

GEO. H. ASHLEY,
State Geologist.

October 25, 1938.

ACKNOWLEDGMENTS

To Drs. Frank M. Swartz and Arthur B. Cleaves, for their coöperation in writing each a chapter for this Bulletin, I am particularly grateful. Almost from the beginning of my official work on the Devonian of Pennsylvania I have enjoyed the advice of Dr. G. Arthur Cooper. Annually, I have gone to Washington to consult with him about my problems, and he has given his time to show me the type region of the Hamilton and has joined me on several occasions in the field in Pennsylvania. To Dr. Kenneth E. Caster, Mr. George H. Chadwick and Mr. Stanley H. Cathcart, I offer sincere appreciation of their advice and field demonstrations in helping to understand the stratigraphy of northwestern Pennsylvania. A like debt is due Mr. D. S. Harding for his demonstrations of the sequence in Susquehanna and Wayne counties. Many others have occasionally contributed, particularly Dr. Winifred Goldring, Dr. A. K. Miller, Professor C. K. Swartz and the late Dr. David White. I wish particularly to thank the editors of the American Journal of Science, the Geological Society of America, the Journal of Geology, and the Pennsylvania Academy of Science for permission to quote from and republish illustrations of my articles which have from time to time appeared in these publications.

BRADFORD WILLARD,
Harrisburg, 1939.

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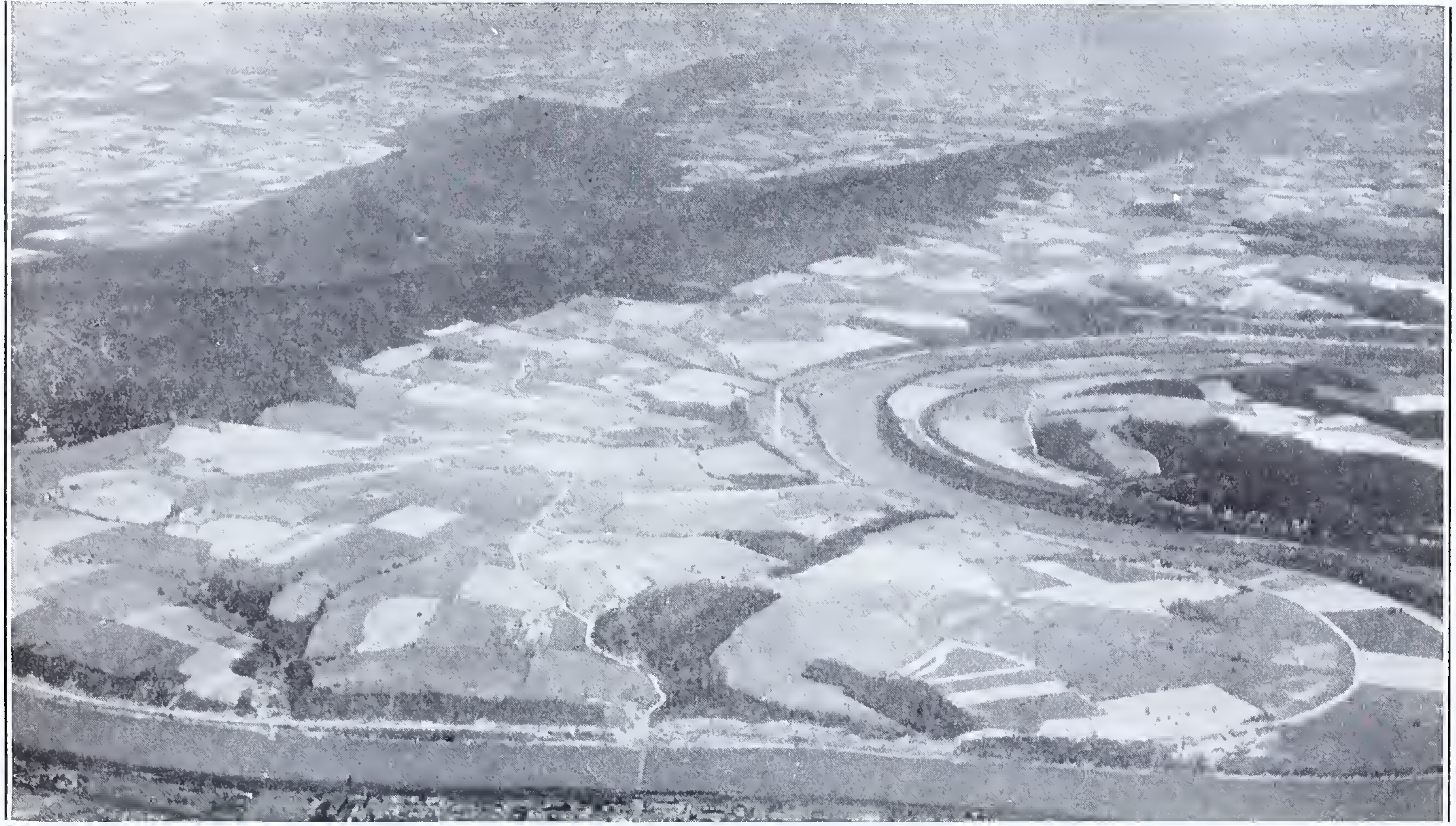

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The Juniata Valley in Perry County, region of the finest Devonian section in Pennsylvania. The aerial view is east from Newport. On the left, Buffalo and Berry Mountains outline the Millersburg syncline, all in Mississippian strata (Pocono and Mauch Chunk). The meandering Juniata River is largely cut in Catskill red beds from Newport Bridge (center foreground) to the foot of the mountains. At the right center is Trimmers Rock, type locality for the Trimmers Rock sandstone of the Portage group, which group underlies most of the right foreground down to the highest Hamilton beds at the extreme right center.

THE DEVONIAN OF PENNSYLVANIA

By Bradford Willard

INTRODUCTION

DEVONIAN DEVELOPMENTS

One hundred years ago the first understanding of what we now call the Devonian system began to form in England. Sedgwick and Murchison had just established interpretations of their Cambrian and Silurian systems in Wales (98, 268).* These systems were known to be separated from the Culm or Carboniferous by a succession of red rocks, the Old Red Sandstone, but the nature of this intervening series was little understood. Hugh Miller's keen observation, set down in his masterly English, had yet to immortalize these rocks and their comparatively rare fossils. The unraveling of the Cambrian and Silurian systems was an important stage in the analysis of the Graywacke, but both Murchison and Sedgwick appreciated that much of Devonshire and Cornwall was underlain by still more rocks of the Graywacke or Transition whose nature, position and relation to other systems were questions unanswered in 1836. Attacking the problem, they presently established that the rocks of southwestern England are older than the Coal Measures, yet disagreed with De La Beche who would have sunk them even below the rest of the Graywacke. It was appreciated that the few fossils then known from these beds were assignable to neither the Cambrian, the Silurian nor the Carboniferous. The resulting explorations by Sedgwick and Murchison culminated in the recognition of the Devonian system. First, however, this Graywacke of the southwest was shown to underlie the Culm or Carboniferous. In this structurally complex area its sponsors were uncertain of their correlations and unable to find an analogy with the Old Red Sandstone across Bristol Channel where that enigmatic series intervened between Carboniferous and Silurian strata. Until more fossils from the Devonshire Graywacke were studied, Sedgwick and Murchison were inclined to suppose that it was merely much altered Cambrian. Fossils eventually being found in some abundance, they were submitted to William Lonsdale in 1837. It is to Lonsdale that the first understanding of the true position of the Devonian system should be attributed; for, after careful study, he concluded that the remains from these rocks, though they showed both Carboniferous and Silurian affinities, belonged to neither system, but were to be interpreted as lying in an intermediate system, between these two and therefore deposited "parallel" to the Old Red Sandstone. Although Murchison and Sedgwick at first hesitated to accept Lonsdale's designation, they were presently convinced of its truth and adopted his views. Subsequent paleontologic work by Sowerby and Phillips, in particular, strengthened their position. Thus was the Devonian established as a system intermediate between the Carboniferous above and the Silurian below and equivalent to the Old Red whose age, conversely, was determined. The original definition of the Devonian system appeared in print in the Transactions of the Geological Society of London for 1839 (187).

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* Numbers in parentheses refer to the Bibliography.

Following the establishment of Devonshire as the type locality for their new system, Sedgwick and Murchison visited the far better sections of the Rhineland, the Harz and the Fichtelgebirge and recognized the better development of the system there on the Continent than in England. Further pioneer studies in Europe were prosecuted during the succeeding years of the middle nineteenth century by Barrande, Beyrich, Losen, Roemer and their colleagues, but this account must turn to North America and the beginnings there of Devonian study which have led up to our present understanding of the system (144, 145).

In the year 1836 when Sedgwick and Murchison were contemplating their Devonshire expedition, American state surveys were beginning to be organized. Those of New York and Pennsylvania were both established in that year, the former only seventeen days younger than the latter. They had their inception at a time when geologic thought was receiving strong impetus, and public interest was in crescendo.

New York Devonian

Correlations between Europe and North America were early tried by the founders of American geology. The tying in of American strata with European was attended with varying approximations to the truth and miscellaneous degrees of success. Realizing the complications accompanying such efforts to cram our succession into the Old World mold, some of our forbears tried to establish geologic nomenclatures of their own, based on type regions on this side of the Atlantic. Emmons's brief "New York System" of a century ago, is one of the earliest attempts. In those beginning years, both James Hall of Albany and Henry D. Rogers of Philadelphia proposed systems of Paleozoic nomenclature. To Hall we attribute the initial deciphering of the New York Devonian. His work, rivaled or surpassed in nineteenth century geological annals only by that of Barrande, may be said to have commenced with the publication in 1843 (110) of his New York State report of "The Survey of the Fourth Geologic District" [New York]. It covered a part of the State which contains some of the best Devonian within its borders. His work was stimulated and his activities accelerated by Murchison's studies, and it is disappointing that the term Devonian appeared before Hall could conscientiously suggest a better, more appropriate designation drawn from New York nomenclature. This Hall himself regretted when he characterized the Devonian as "a system founded in error." With the passing years, the New York sequence became ever better understood, and complicated nomenclature grew up as subdivisions multiplied until the present unwieldy sequence evolved.

It came to be realized early that in New York State a Paleozoic sequence was exposed which in a great measure outrivaled Europe's best. Particularly is this true of the unbroken succession of Devonian rocks which, with their abundant marine faunas and equivalent fresh-water facies, spreads over so large a part of the Empire State. Eventually the whole question of nomenclature settled down to a species of compromise between Europe and America, at least in so far as American geologists were concerned. The major European units, the systematic names, were largely adopted in America, but for lesser divisions, local, geographic names became the fashion until the New York Devonian sequence grew to be the type for much of North America, particularly for the eastern United States or the Appalachian region.

First Pennsylvania Survey

Henry Darwin Rogers was appointed first State Geologist of Pennsylvania in 1836 (136, 108), and continued to hold office through a broken but productive administration of more than twenty years, climaxed by his final report, "The Geology of Pennsylvania," in 1858 (177). Before the end of 1836, the First Annual Report (171) was off the press. It would be difficult to find in an equally brief account of that time as much "meat" as this tiny, paper-covered volume contains. In it is not only a report of the Survey's personnel and activities for the first year, but a statement of the results of that season's field work. In that initial year was established the basis for the future interpretation of the Paleozoic column for Pennsylvania. It is remarkable that, hampered by inadequate funds, a dearth of trained helpers, operating almost before transportation began to shift from stage coach and Conestoga wagon to canal and railroad, and working in a nearly unmapped region, much of which was still virgin wilderness so wild that even the pack train proved impracticable, such results should be obtained.

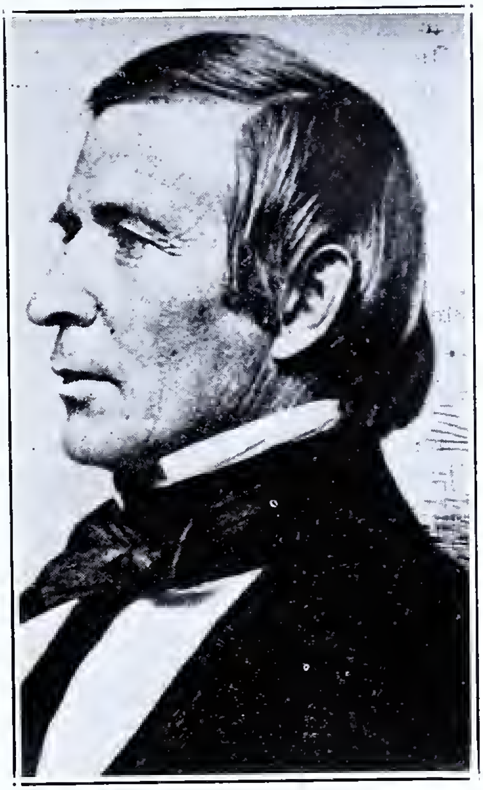

Figure 1. **Henry D. Rogers, First State Geologist of Pennsylvania.**
After J. W. Gregory.

To his "Appalachian System" Rogers assigned twelve (later thirteen) divisions, many of which, with small changes, are valid today. Though modern stratigraphic boundaries are not always drawn at the same places, Rogers determined his with a precision based upon firm reasoning which bespeaks an acuteness of observation seldom rivaled today in our best trained men operating with all the advantages of modern science and equipment. Rogers's divisions 6, 7, 8 and 9 embrace the strata that include the highest Silurian through to the base of the Mississippian, that is, a little more than the entire Devonian. The Second Annual Report of Rogers, 1838 (172), amplified the First and recognized, because of the addition of the Cambrian quartzite made known in the interim of field work since 1836, thirteen instead of the original dozen Paleozoic divisions. It is in this report that he began to use Roman numerals for the "formations," a usage which even today has not been entirely abandoned by our State Survey (99). Thus, X is the Pocono of early Mississippian and IX, VIII, VII and VI are assigned to the Devonian. "Formation" VI evidently embraced beds of Silurian age, but we should note that it is only in very recent years that any semblance of agreement has been reached as to where the Devonian-Silurian boundary should be drawn in Pennsylvania. His unequivocal definitions make recognition of the several major divisions clear. Passing over the remaining four annual reports (173, 174, 175, 176), which contribute little on the Devonian, to "The Geology of Pennsylvania," 1858 (177), we have one of the outstanding State Survey reports of the nineteenth century.

Aside from the contents, the 1858 report is to be admired for its composition. The carefully drawn, precisely printed maps, the clearly engraved cuts based upon Lehman's artistic field sketches, and the quaint, naturalistic sections are truly beautiful. The contents are worthy of such presentation and merit special eulogy. It is here that Rogers's ideas on nomenclature culminated. They deserve comment if for no other reason than for their grotesqueness. No student of the history of American geology has escaped noting the series of Latin terms that Rogers introduced to designate the major Paleozoic divisions. Disgusted with European sequences and names and unwilling to adopt "imported" New York terms which he recognized but believed of local value only, Rogers, to quote the late J. B. Woodworth,* published "a bizarre, Bizantine Latin nomenclature" whose terminology was wholly unrelated to lithology, fossils, localities or any other distinguishing geologic feature or phenomenon. Taking Latin divisions of the night and day, he used them for "formation" names, divisions essentially of present-day systemic value. At best it was an application of abstract chronology to concrete matter. It may have been logical, but it was too outlandish, too cumbersome, too little comprehended to be well received. Save for adoption in Virginia and Maryland for a short time, Rogers's Latin names seem to have made little contemporaneous impression. It is interesting to observe that he most meticulously designated the New York equivalents of all his divisions, perhaps tacitly accepting Hall's work as the standard, though not openly admitting such a concession. However, names being one thing and definitions another, we may turn to the text of Rogers's report. In describing each unit, his terminology may be slightly archaic at times ("slate" for "shale", etc.), but his meaning is perfectly clear. The Devonian in the 1858 report is divided as follows:

PONENT SERIES

PONENT RED SANDSTONE *(Catskill Group of New York).*—In its fullest development this is a mass of very thick alternating red shales, and red and grey argillaceous sandstones. It has very few organic remains. Among them is *Holoptychius*, and one or two other remarkable fossil fishes, of genera distinctive of Old Red Sandstone. This formation has its maximum thickness in its southeastern outcrops, where it measures more than 5000 feet.

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* Lectures on the History of Geology delivered at Harvard University.

VERGENT SERIES

VERGENT SHALES *(Chemung Group of New York)*.—A thick mass of grey, blue, and olive-coloured shales, and grey and brown sandstones. The sandstones predominate in the upper part, where the shales contain many fossils. Thickness in Huntingdon, 3200 feet.

VERGENT FLAGS *(Portage Flags of New York)*.—A rather fine-grained grey sandstone in thin layers, parted by thin alternating bands of shale. It abounds in marine vegetation. Thickness in Huntingdon, 1700 feet.

CADENT SERIES

CADENT UPPER BLACK SLATE *(Genessee Slate of New York)*.—A brownish-black, and in some regions bluish-black, very fissile slate, characterized by its small and delicate fossils; many of them, as *Leptaena setigera*, identical with those of the Cadent Lower Black Slate. It is the lowest known horizon of Carboniferous plants. Thickness in Huntingdon, 300 feet.

CADENT SHALES *(Hamilton Group of New York)*.—Bluish-grey, brownish, and olive-coloured argillaceous shales, including in some districts thin beds of dark-grey and brown sandstone. It has many fossils, particularly bivalve shells. Thickness in Huntingdon, 600 feet.

CADENT LOWER BLACK SLATE *(Marcellus Slate of New York)*.—A black and highly bituminous slate, graduating upwards into a dark-blue argillaceous shale. In some districts these are overlaid by greenish-grey sandy shales. In Pennsylvania, Virginia, and Tennessee, a thin argillaceous limestone generally occurs near the bottom of the black slate. The fossils, with few exceptions, are of diminutive size, most of them identical with those of the Cadent upper black slate. Thickness in Huntingdon, 250 feet.

POST-MERIDIAN SERIES

POST-MERIDIAN LIMESTONE *(Upper Helderberg or Corniferous of New York, part of Cliff Limestone of Western States)*.—In North-Eastern Pennsylvania, New Jersey, and New York, a blue, and in some portions a sparry limestone, including bands and nodules of chert. In Upper Canada and the Western States it is light-grey and straw-coloured, and sometimes oolitic, still retaining the chert. Among its many fossils are numerous large corals, as *Favosites Gothlandica*, *Favistella*, &c., and characteristic shells, as the *Pleurorhynchus trigonalis*. Its thickness east of the Delaware Water-Gap is about 80 feet.

POST-MERIDIAN GRITS *(Caudi-Galli and Schoharie Grits of New York)*.—A formation containing two members hitherto only met with in a limited district in New York. The lower member is a dark-greenish argillaceous rock, recognisable by a peculiar plant, resembling somewhat a cock's tail. The upper member is a more calcareous grit. This formation is largely developed in New Jersey, north-east of the Delaware Water-Gap, where it has a thickness of 300 feet.

MERIDIAN SERIES

MERIDIAN SANDSTONE *(Oriskany Sandstone of New York)*.—A coarse, yellowish, calcareous sandstone, graduating near its upper limit into a fine-grained quartzose conglomerate, and becoming in its lower beds a coarse arenaceous limestone, characterised by the *Atrypa elongata*, *Spirifer arenosus*, and other remarkable large Brachiopodous shells. Its greatest thickness on the Juniata is about 150 feet.

MERIDIAN SLATE.—A dark ash-coloured and blackish slate, passing upward into a dark ashy grey sandy calcareous rock. It has its greatest thickness on the Upper Juniata, near Frankstown, where it is 170 feet.

PRE-MERIDIAN SERIES

PRE-MERIDIAN LIMESTONE *(Lower Helderberg Limestone of New York).*—A diversified calcareous formation, usually of some shade of greyish blue. It is argillaceous and flaggy in its lower beds, and shaly towards the middle. It frequently contains layers and nodules of chert, especially near its upper limits. It has many characteristic fossils, the *Pentameris galeatus*, and other shells, with corals. The average thickness of this rock is between 50 and 100 feet.

SCALENT SERIES.*

SCALENT LIMESTONE *(Water Lime Group of New York).*—A blue flaggy limestone, sometimes containing bands of chert. Certain portions have a thinly-bedded, wavy stratification [Tonoloway]. It is frequently highly magnesian, and is extensively employed, especially in New York, for making hydraulic cement. This rock contains the *Cytherina alta*, *Tentaculites ornatus*, and a few other distinctive fossils. Thickness on the Juniata, 250 feet.

To these descriptions by Rogers of those of his divisions that embrace the Devonian, it is necessary to add his paragraph on the Vespertine Series (Pocono of today) because of references which I shall occasionally make thereto.

VESPERTINE SERIES

VESPERTINE CONGLOMERATE AND SANDSTONE.—White, grey and yellowish sandstone, alternating with coarse siliceous conglomerates, and dark-blue and olive-coloured slates. It frequently contains beds of black carbonaceous slate, with one or more thin seams of coal. The only organic remains are fragments of coal plants; some of these are specifically, and even generically, different from those of the Seral coal series. It has its greatest thickness near the Susquehanna, where it measures 2660 feet.

Many are the data and great the detail, especially anent geographic distribution, left us by Henry D. Rogers. Most of the facts are as pertinent today as in 1858. We marvel at their wealth and how he was able to produce so accurate a State geologic map (177). Not intimidated by State boundaries, Rogers traveled far, and those of his writings that suggest correlations of Pennsylvania's rocks with extraterritorial sections show a wide and accurate appreciation of Appalachian stratigraphy. We may smile smugly at the theories of dynamic geology of the brothers Rogers, but we must listen with earnest attention when Henry D. talks on the stratigraphy of Pennsylvania. Even though he clothes his stratigraphy in impossible terminology, he gives us a succession that in every way is favorably comparable with that then known for the New York Paleozoic. Had the subsequent work of our State Surveys paid more attention to pure and less to applied geology, as has been the case in New York, and simultaneously looked more often beyond our own borders, perhaps we might today point to Pennsylvania, not New York, as having the best understood Paleozoic succession in eastern North America.

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* This series is largely to be correlated with our highest Silurian as used today, but its uppermost member embraces part of the Helderberg group, and therefore is quoted here in part.

Second Pennsylvania Survey

The Second Pennsylvania Survey, which ran for some score years after its founding in 1874, is often referred to as "the Lesley Survey" after its leader, the brilliant Joseph Peter Lesley, in contradistinction to the First or "Rogers Survey." Lesley tripped off his survey's avalanche of publication with an interesting book (Volume A) on the history of Pennsylvania geology (136). He himself had been a member of the First Survey and was amply qualified to leave such a record, and many are the personal touches which he adds in dry, often facetious humor. To cite but one, mentioning the mysterious disappearance of the collection of fossils made by the First Survey and ostensibly deposited in the State Museum, he remarks that they turned up in the State Lunatic Asylum! Lesley's antipathy for fossils was apparently as strong as his gift of sarcasm.

From Lesley's own statement, he was the first geologist to receive a specific assignment covering Devonian strata in the State. When, in 1840, he joined the First Survey, he was set at work mapping the Devonian formations cropping out around the anthracite basins. Judging from some of the mapping of this region, particularly the Pocono Plateau, work which Lesley acknowledged his own, his maiden assignment and subsequent work on the Devonian in the northeast has brought him few laurels. Nor were other members of his Second Survey staff above reproach in this matter. Of the scores of volumes published, many include descriptions and maps of parts of the Devonian system, but few carry statements regarding that system which are of sufficient accuracy still to be applicable. All must be rechecked and used with utmost caution. The mapping is generally reliable, though hardly an improvement over that of the Rogers Survey. Occasionally serious errors were made. Everywhere, speaking particularly of the Devonian, there is a lack of detail, showing an inability of the workers to apply stratigraphic and paleontologic principles. The mere fact that so many independent workers studied their assigned areas and failed to coördinate them shows not only a lack of proper organization of the staff, but a failure of the Chief to establish essential coöperation and indispensable exchange of data among his personnel. Always, the Second Survey is to be mistrusted when Devonian fossils are cited. Distinctive fossils, even entire faunas, were sometimes completely missed or incorrectly classified. Thus, *"Spirifer" disjunctus,* so important in separating the Chemung

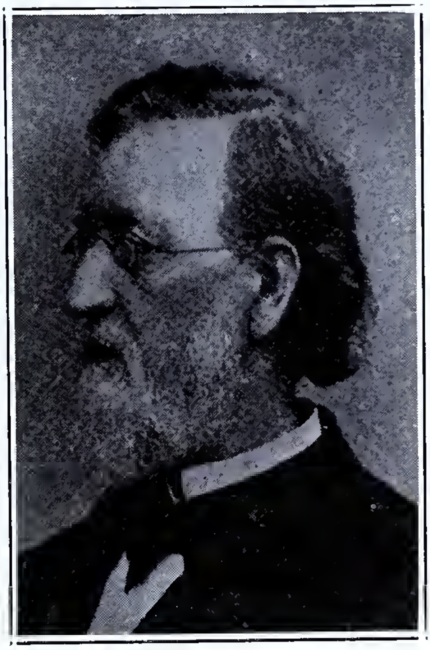

***Figure* 2. Joseph P. Lesley, Second State Geologist of Pennsylvania.**
After G. P. Merrill.

from the Portage, was not recognized in regions where it is common; and, conversely, was reported widely over areas where it is now known to be totally absent. The Tully and Onondaga faunas were generally either missed completely or incorrectly identified, the Marcellus and "Genesee" were confused, and the Hamilton, Portage and Chemung were sometimes mapped together as a single unit, presumably through inability to separate their faunas. Nevertheless, the Second Survey did carry on its rolls names of men to whom homage is due for the high quality of their pioneer achievements in Devonian stratigraphy.

Figure 3. **I. C. White, outstanding stratigrapher of the Second Pennsylvania Geological Survey, from a portrait taken while a member of the staff.**

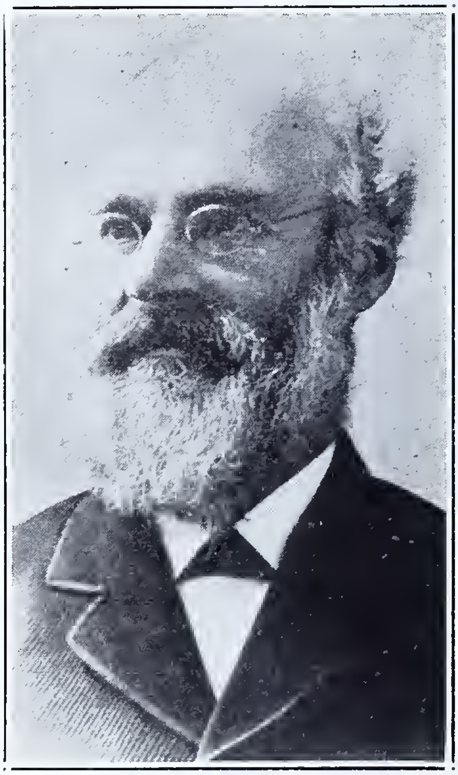

Figure 4. **E. W. Clapole, interpreter of the Devonian of the lower Juniata Valley.**
Photograph furnished through the courtesy of Antioch College, Yellow Springs, Ohio

In reading their reports one sometimes is tempted to feel that, had they been unhampered by the interfering, tampering and nullifying influence of the State Geologist, they would have produced far more creditable accounts. The extensive and on the whole acute observations of I. C. White are a lasting credit to his memory. They represent at once the most widespread and the most accurate work on the system by any member of Lesley's staff. The steady improvement noticeable in White's reports is noteworthy. Credit is also due J. J. Stevenson and E. W. Claypole, both of whom did above average work on our Devonian. The rest of the staff now and then left an excellent bit of observation or clever deduction, but their reports on the Devonian are throughout quite mediocre. Perhaps Lesley appreciated these deficiencies or regretted his own interferences, for he apparently tried to patch up and gloss over these faults in his Summary Final Report (137), but in most instances his attempts resulted rather pathetically in merely emphasizing the inaccuracies already extant.

Third Pennsylvania Survey

The expiration of the Second Survey just before the turn of the century was followed by a period when studies of Pennsylvania's geology languished, and contributions to its Devonian stratigraphy and paleontology were almost nil. For over thirty years only a few sparks shining in this Stygian environment prevented complete extinction of the light. Such were struck by Henry S. Williams (265), E. M. Kindle (126, 127), Charles S. Prosser (161), Joseph Barrell (12), J. B. Reeside (167) and Charles Butts (19, 20, 21, 22), who added valuable data during this time, and may be looked upon as among the first modernists in the application of stratigraphy and paleontology to our Devonian. Except for Kindle's work on the Onondaga (127), their observations were chiefly confined to small areas. The Third Survey's official work was almost valueless stratigraphically, Fettke's work excepted (88), but contemporaneous contributions through coöperative publication with the United States Geological Survey are not devoid of value. Folios of that time contain facts of use today in our Devonian studies, but, like all folios, these have the disadvantage of publishing good maps supported by too brief descriptions of highly restricted areas. It is interesting to note here how much of the data on our Devonian has been accumulated through official, State and Federal, sources and how little has been added by independent workers, and this in a region of untold potential interest.

Fourth Pennsylvania Survey

The Fourth Survey, the present Topographic and Geologic Bureau, is the first officially to sponsor detailed stratigraphic and paleontologic studies unhindered by the incubus of "the economic aspect." Thus far its work has been concentrated mostly upon the Silurian and Devonian systems. The studies by Dr. Frank M. Swartz upon the former show new details of that system and a wealth of stratigraphic and paleontologic problems that are fully as interesting and significant as are those of the Devonian of the present report. It has been my privilege to be assigned the study of the Devonian system in Pennsylvania. This investigation was prefaced by self-supported work in Pennsylvania and New Jersey pursued at odd times for a dozen or more years prior to assuming official connections at Harrisburg. During the summer of 1929, under temporary appointment with the Survey, I worked on the Silurian of the State. Commencing the following year under full-time appointment, and continuing, save for devoting part of the 1936 and 1938 field season to Ordovician problems, I have given practically all my time in the field to studies of Devonian and, to a less degree, the closely allied Mississippian systems.

This work has been supplemented by out-of-State trips during which exposures of the Devonian system in Maine, New Hampshire, Massachusetts, New York, New Jersey, Maryland, Virginia, West Virginia and the southern Appalachians as far as Alabama have been observed. Often these excursions were conducted in the company of specialists in those several regions. Because Dr. Swartz in his Silurian studies in Pennsylvania has included the lowest Devonian group, the Helderberg, in his work, I have given only casual attention to that very interesting succession, and am indebted to Dr. Swartz for preparing Chapter II on the Helderberg group. It appears in this report under his name. Our respective assignments being somewhat unrestricted as to their mutual boundaries, neither of us has given the Oriskany thorough attention. Both collected data on it and each mentioned it casually, but it remained incompletely worked until 1936. At the beginning of that season, the Survey granted Dr. Arthur B. Cleaves a temporary appointment to study the Oriskany group of Pennsylvania. In 1937 he continued this work under full-time appointment. Chapter III on the Oriskany group by Dr. Cleaves is essentially the report of his Survey work. It should be added that Dr. Cleaves had previously spent two field seasons in private study of the New Bloomfield quadrangle, an area embracing some of the most interesting Oriskany of the State. I myself have spent considerable time in the field with him. Up to the time of Dr. Cleaves's studies, the only things surely known about the Oriskany in Pennsylvania seem to have been its geographic distribution and its value as a source of glass sand and natural gas. We are now able to publish a discussion of its lithology, fossil contents, and allied data.

During the last five or six years a few geologists have become interested in our Devonian sequence, chiefly in northwestern Pennsylvania. Notable among them are Dr. K. E. Caster and Mr. G. H. Chadwick, whose controversial papers on the surface correlations imply that much is yet to be learned about that interesting part of the State. The development of the northern gas fields has added subsurface facts. While this independent investigation has been going on, the State has financed work in this region, a notable result being Dr. Charles R. Fettke's report on the Bradford Oil Field (94). Here subsurface geology is applied at its best. The partially unpublished Survey work of Mr. S. H. Cathcart should prove a masterly contribution to a final understanding of this district. Because the several workers in this field, many of whom have had long experience in the area, have not completed their studies, I myself have not made exhaustive studies of the Devonian of northwestern Pennsylvania. I have, however, gone over the region with those already familiar with it and have supplemented such tours by observations of my own. In constrast, I have concentrated my studies elsewhere on the Middle and Upper Devonian, to which has necessarily been added much study of the Lower Mississippian or Pocono over the rest of the State. These studies have largely omitted the Lower Devonian for reasons cited. My observations have been focused on the great expanses of Devonian strata that traverse the State from the south-central border to the northeastern quarter, spread over many square miles in the central regions, crop out below the scarp of the Allegheny Front, form the Pocono Plateau, and are exposed continually across the northern tier of counties. It is to the Middle and Upper Devonian stratigraphy of these areas, then, that most of my studies have been dedicated, and it is a discussion of these that makes up the body of this report.

CHAPTER I

THE DEVONIAN SYSTEM IN PENNSYLVANIA

AREAL DISTRIBUTION

Devonian rocks in Pennsylvania occupy a greater part of the surface of the State than those of any other system except the Pennsylvanian (99, 8, 244). Their greatest expanse is in the northeastern corner of the State where they are exposed over practically all Susquehanna, Wyoming, Wayne, Pike and Monroe counties. Extending westward along the northern border, Devonian rocks occupy large parts of Bradford, Tioga, Potter, McKean, Warren and Erie counties with lesser areas south into Crawford, Cameron, Lycoming, Sullivan and Luzerne. Throughout much of this northern and northeastern area, the Devonian is composed of continental rocks, but the change to marine sediments begins northwestward from the Anthracite Fields and becomes progressively more complete westward to the nearly total exclusion of freshwater beds in the northwestern corner of Pennsylvania. The Devonian marine strata with a varying proportion of non-marine also extend in a southwesterly direction from Luzerne and Monroe counties, circumscribe the Anthracite Fields and occupy much of the Susquehanna and Juniata valleys between Harrisburg and Williamsport and westward. Throughout this mountainous region, the Devonian formations weave back and forth as a series of great zigzag traces across Dauphin, Perry, Northumberland, Juniata, Snyder, Union, Columbia, Montour and Lycoming counties. A band

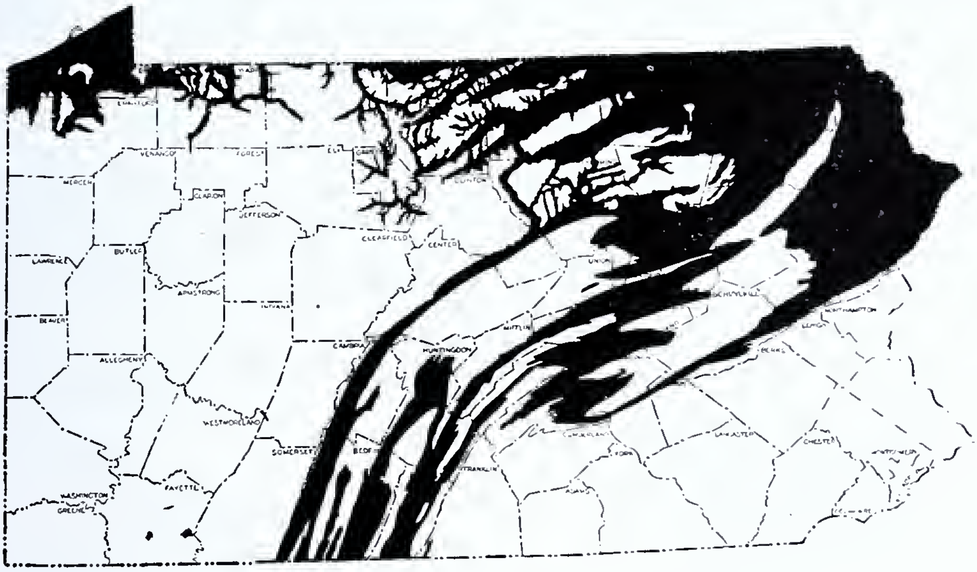

Figure 5. Sketch map showing distribution of Devonian system in Pennsylvania.

of Devonian follows the Allegheny Front escarpment from Lycoming County west and south into Maryland. In the region between the Allegheny Front and the middle Susquehanna Valley, Devonian rocks constitute a large part of the terrane. They surround the Broad Top coal basin and extend south, through Bedford and Fulton counties, and north into Huntingdon and Mifflin, there to tie in with the areas along the Juniata and Susquehanna valleys in middle Pennsylvania. Finally, the great, obliquely north-northeast trending anticlines crossing southwestern Pennsylvania bring the top of the Devonian to the surface in a few scattered spots, chiefly in Fayette, Westmoreland, Cambria and Indiana counties.

SUBDIVISIONS OF THE DEVONIAN

The Devonian in Pennsylvania is abundantly subdivided. To give all the recognized units in a single table would be comprehensive but too complicated. The sections which should be cited to obtain a clear and fairly complete picture of the whole are so many that they must be presented in groups. It is not intended to show precise correlations among these tables; they must be postponed for a later chapter. Thicknesses are omitted in this tabulation, nor are other than general references to fauna included. Mention of minor variations has been deleted in most cases, since they are usually quite local and may be better handled as each unit is fully described in its appropriate place. The intent is here to set down characteristic Devonian sequences for particular parts of the State.

TABLE I. GENERALIZED DEVONIAN SEQUENCE IN PENNSYLVANIA

Upper Devonian
  Conewango group
  Conneaut group
  Canadaway group
  Chemung group
    Wellsburg formation
    Cayuta formation
  Portage group
    Fort Littleton formation
      Trimmers Rock sandstone
      Brallier shale
      Losh Run shale
      Harrell shale
    Rush formation
      Burket shale
      Tully limestone

Catskill continental facies equivalent in northeastern counties.

Middle Devonian

(Central Pennsylvania)	(Eastern Pennsylvania)
Hamilton group	Hamilton group
Mahantango formation	Mahantango formation
With or without the Montebello sandstone. Moscow, Ludlowville and Skaneateles faunal facies recognized.	Moscow, Ludlowville and Skaneateles faunal facies and corresponding lithologic variations recognized.
Marcellus formation	Marcellus formation
Onondaga group	Onondaga group
Selinsgrove limestone	Buttermilk Falls limestone
Needmore shale	Esopus shale

Lower Devonian
Oriskany group
Ridgeley sandstone
Shriver chert
Helderberg group
Mandata shale
New Scotland formation
Coeymans formation

TABLE II. NORTHEASTERN PENNSYLVANIA

Susquehanna County	**Wayne and Pike Counties**
MISSISSIPPIAN SYSTEM (lower part)	
Pocono formation	Pocono formation
Griswolds Gap conglomerate	Griswolds Gap conglomerate
DEVONIAN SYSTEM (upper part)	
CATSKILL FACIES GROUP	CATSKILL FACIES GROUP
Mt. Pleasant red shale	Mt. Pleasant red shale
Elk Mountain sandstone	Elk Mountain sandstone
Cherry Ridge red beds Dyberry glomerate	Cherry Ridge red beds Dyberry glomerate Pimple Hill conglomerate
Honesdale sandstone	Honesdale sandstone
Damascus red shale	Damascus red shale
CHEMUNG GROUP (in part)	
New Milford formation* Luthers Mills coquinite* Lanesboro member* Kingsley red shale* Cayuta formation*	Shohola formation Paupack sandstone Barryville member
PORTAGE GROUP* (Concealed)	Delaware River flags Analomink red shale PORTAGE GROUP (marine) Trimmers Rock sandstone*

Western Bradford County
MISSISSIPPIAN SYSTEM (lower part)
Pocono formation (and Knapp?)

DEVONIAN SYSTEM (upper part)
Catskill facies group
Elk Mountain or Oswayo sandstone
Cherry Ridge red beds (Cattaraugus, "Blossburg")
Honesdale sandstone*
Damascus red shale*
Luthers Mills coquinite*
Chemung group
New Milford in part*

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* Units marked with asterisk are partly or wholly marine. Uppermost New Milford beds are post-Chemung; in the east they are continental and assigned to the Catskill facies group; in the west, they carry the Luthers Mills coquinite. Remainder of New Milford is probably Wellsburg in age and partly continental, partly marine. Barryville member is Chemung age, but Paupack sandstone is wholly or partly post-Chemung and equal to part of or all of the New Milford. Delaware River flags and Analomink red shale are of Portage age, but belong with the Catskill facies, being non-marine as contrasted with the Trimmers Rock sandstone which is marine Portage.

TABLE III. GENERALIZED SEQUENCE FOR NORTHWESTERN PENNSYLVANIA

McKean and western Potter counties

- MISSISSIPPIAN SYSTEM (lowest part)
  - Knapp conglomerate*
  - Kushequa shale*
- DEVONIAN SYSTEM (upper part)
  - Conewango group
    - Oswayo shale*
      - Roystone coquinite*†
    - Cattaraugus red shale
    - Panama conglomerate*
  - Conneaut group
    - Chadakoin shale* ("stage" of Caster)
    - Cuba sandstone*
  - Canadaway group*
  - Chemung group*

TABLE IV. COMPOSITE MARINE SEQUENCE FOR NORTHWESTERN PENNSYLVANIA‡

- MISSISSIPPIAN SYSTEM (lowest part)
  - Knapp conglomerate
  - Kushequa shale
- DEVONIAN SYSTEM (upper part)
  - Conewango group
    - Riceville formation
      - Oswayo shale
      - Roystone coquinite
    - Venango formation
      - Woodcock sandstone
      - Tuna-Kilbuck conglomerate lens
      - Saegerstown shale
      - Pope Hollow conglomerate }
      - North Warren shale } Salamanca formational suite of Caster.
      - Bimber Run conglomerate }
      - Amity shale
      - Panama conglomerate
  - Conneaut group
    - Chadakoin formation
      - Tanners Hill red zone
      - Ellicott shale
      - Dexterville shale
      - Lillibridge sandstone
    - Girard formation
      - Girard shale
      - Cuba conglomerate
  - Canadaway group }
    - Northeast shale }
    - Shumla sandstone }
    - Westfield shale } Not all of these are necessarily distinguished in Pennsylvania. They are I. C. White's "Portage."
    - Laona sandstone }
    - Gowanda beds }
    - Dunkirk black shale }

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* Units marked with asterisk are partly or wholly marine.

† This coquinite Caster (33) renamed Flatiron, but Roystone is in good standing.

‡ Partly after Caster (33), and Chadwick (47, 51), including units shown in southwestern New York, but not exposed in Pennsylvania. Westfield is preoccupied, but as it is applied to beds not exposed in Pennsylvania, a substitute is not now proposed. Cf. U. S. Geol. Survey Bull. 896, 1938, pp. 2306-7.

    - Chemung group†
      - Wellsburg formation with "Fall Creek" conglomerate at top
      - Cayuta formation
    - Portage group
      - (Not exposed)

TABLE V. APPALACHIAN RIDGE AND VALLEY REGION

- **Monroe County**
  - Mississippian System (absent)
  - Devonian System
    - Upper Devonian
      - Catskill facies group
        - Mount Pleasant red beds
        - Elk Mountain sandstone
        - Cherry Ridge red beds
          - Pimple Hill conglomerate
        - Honesdale sandstone
        - Damascus red shale (and Shohola?)
        - Delaware River flags*
        - Analomink red shale*
      - Portage group (highest marine)
        - Fort Littleton formation
          - Trimmers Rock sandstone
            - Laurens beds with Tully elements at base
    - Middle Devonian
      - Hamilton group
        - Mahantango formation
          - Moscow faunal facies in upper part
          - Ludlowville faunal facies in middle with a storm roller zone in lower part and Centerfield coral reef near base
          - Skaneateles faunal facies in lower part
        - Marcellus formation
          - Brodhead shale
          - Shamokin (?) shale
      - Onondaga group
        - Buttermilk Falls limestone
        - Esopus shale
    - Lower Devonian
      - Oriskany group
      - Helderberg group
        - Port Ewen shale
        - Becraft limestone (locally)
        - New Scotland shale
        - Coeymans limestone including "Stormville" sandstone

- **Lehigh River**
  (below Mauch Chunk)
  - Mississippian System (lower part)
    - Pocono formation
  - Devonian System
    - Upper Devonian
      - Catskill facies group
        - Cherry Ridge red beds (Mount Pleasant (?) included)
          - Pimple Hill conglomerate
        - Honesdale sandstone
        - Damascus red beds

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† Several divisions of the Chemung are recognized in southwestern New York.

* The starred units of the Catskill are of Portage age.

      - Portage group
        - Fort Littleton formation
          - Trimmers Rock sandstone
        - Rush formation
          - Burket shale
          - Tully limestone
    - Middle Devonian
      - Hamilton group
        - Mahantango formation
          - Moscow faunal facies in upper part with *Vitulina* zone at top
          - Ludlowville faunal facies in middle part with a storm roller zone in lower portion and Centerfield coral reef near base
          - Skaneateles faunal facies in lower part
            - Probable equivalents of the Berwyn and Delphi of New York present
        - Marcellus formation
          - Brodhead shale
      - Onondaga group
        - Buttermilk Falls limestone
        - Selinsgrove limestone
        - Hazard paint ore
        - Esopus shale
        - Palmerton sandstone
        - Bowmanstown chert
    - Lower Devonian
      - Oriskany group
        - Ridgeley sandstone
      - Helderberg group
        - New Scotland chert and Coeymans (?) sandstone

- **Schuylkill Valley** (generalized section)
  - Mississippian System (lower part)
    - Pocono formation
  - Devonian System
    - Upper Devonian
      - Catskill facies group
        - Cherry Ridge red beds
          - Pimple Hill conglomerate
        - Honesdale sandstone
        - Damascus red beds
      - Portage group
        - Fort Littleton formation
          - Trimmers Rock sandstone
        - Rush formation
          - Burket shale
          - Tully (?) shale*
    - Middle Devonian
      - Hamilton group
        - Mahantango formation
          - Moscow faunal facies in upper part
            - *Vitulina* zone near top
          - Ludlowville faunal facies in middle part with a storm roller zone in lower portion and Centerfield coral reef near base
          - Skaneateles faunal facies in lower part,
            - Berwyn and Delphi of New York doubtfully represented
          - Fort Hunter† sandstone near base

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* Traces of Tully have been found in the Schuylkill Valley region.

† Called Rockville by Willard and Cleaves; name pre-occupied.

- Marcellus formation
  - Brodhead shale
  - "Chittenango" (Shamokin?) shale
- Onondaga group
  - Selinsgrove limestone
  - Esopus (?) shale
- Lower Devonian
  - Oriskany group
    - Ridgeley sandstone
    - Shriver (?) chert
  - Helderberg group

- **Susquehanna-Juniata Valleys Region** (chiefly Perry and west-central Dauphin counties).
  - Mississippian System (lower part)
    - Pocono formation
  - Devonian System
    - Upper Devonian
      - Catskill facies group
        - Cherry Ridge red beds
          - Pimple Hill conglomerate (or sandstone)
        - Honesdale sandstone
        - "Damascus" red beds with which are included Kings Mill sandstone and Dellville shale, both non-red units with Chemung fossils.
      - Chemung group (see also "Damascus" red beds)
      - Portage group
        - Fort Littleton formation
          - Parkhead sandstone (?)
          - Trimmers Rock sandstone
          - Losh Run shale
          - Brallier and Harrell shales, inseparable here
        - Rush formation
          - Burket shale
          - Tully limestone and shale
    - Middle Devonian
      - Hamilton group
        - Mahantango formation
          - *Vitulina* zone at top in shale with Moscow faunal facies
          - Deep Run shale probably present
          - Montebello sandstone dominant element. Includes faunas assignable to the Ludlowville, Skaneateles and probably Centerfield and perhaps "Colgate".*
        - Marcellus formation
          - Mahanoy black shale
          - Mexico sandstone
          - Turkey Ridge sandstone
          - Shamokin shale
      - Onondaga group
        - Selinsgrove limestone
        - Needmore shale
    - Lower Devonian
      - Oriskany group
        - Ridgeley sandstone
        - Shriver chert

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* The name Colgate as used in New York is preoccupied.

- Helderberg group
  - Mandata shale and chert
  - New Scotland formation
  - Coeymans limestone

Forks of the Susquehanna (Sunbury, Selinsgrove Junction, etc.)

- Mississippian System (lower part)
  - Pocono formation
- Devonian System
  - Upper Devonian
    - Catskill facies group, undifferentiated
    - Portage group
      - Fort Littleton formation
        - Parkhead sandstone (?)
        - Trimmers Rock sandstone
        - Losh Run shale
        - Brallier shale
        - Harrell shale
      - Rush formation
        - Burket shale
        - Tully limestone and limy shale
  - Middle Devonian
    - Hamilton group
      - Mahantango formation
        - Includes faunal elements assignable to the Moscow, Ludlowville and Skaneateles
      - Marcellus formation
        - Brodhead shale
        - Union Springs shale
    - Onondaga group
      - Selinsgrove limestone
      - Needmore shale
  - Lower Devonian
    - Oriskany group
      - Ridgeley sandstone
      - Shriver chert
    - Helderberg group
      - Mandata shale
      - New Scotland limestone
      - Coeymans limestone (?)

TABLE VI. ALLEGHENY FRONT

Lock Haven Region

- Mississippian System (lower part)
  - Pocono formation
- Devonian System
  - Upper Devonian
    - Catskill facies group
      - Oswayo sandstone (?) in upper part
      - Cattaraugus and older red beds
    - Chemung group, undifferentiated
    - Portage group
      - Fort Littleton formation
        - Brallier shale
        - Harrell shale
      - Rush formation
        - Burket shale
        - Tully limestone

- Middle Devonian
  - Hamilton group
    - Mahantango formation
    - Marcellus formation
  - Onondaga group
    - Needmore shale
- Lower Devonian
  - Oriskany group
    - Ridgeley sandstone
    - Shriver chert
  - Helderberg group

Bedford County, generalized

- MISSISSIPPIAN SYSTEM (lower part)
  - Pocono formation
- DEVONIAN SYSTEM
  - Upper Devonian
    - Catskill facies group, undifferentiated, but containing local conglomerates and at top Oswayo (?) sandstone
    - Chemung group, doubtfully divisible on lithology
    - Portage group
      - Fort Littleton formation
        - Parkhead sandstone
        - Brallier shale
        - Harrell shale
      - Rush formation
        - Burket shale
        - Tully limestone
  - Middle Devonian
    - Hamilton group
      - Mahantango formation
        - Locally differentiated into various sandstones and shales
      - Marcellus formation
    - Onondaga group
      - Needmore shale
  - Lower Devonian
    - Oriskany group
      - Ridgeley sandstone
      - Shriver chert
    - Helderberg group (at Cumberland, Md.)
      - Mandata shale
      - New Scotland limestone
      - Coeymans limestone

LIMITS OF THE DEVONIAN

Upper limit. The definitions of the upper and lower limits of the Devonian system in Pennsylvania have long furnished fuel to the fires of disagreement. Because, in by far the greater part of the State, the closing events of the Devonian period and the opening activities of the Mississippian are recorded in nearly barren, continental deposits punctuated here by no recognized orogeny, a sharp separation between these systems was long unknown or unrecognized generally. The literature choruses "Transitional Beds" or "Passage Beds". In some sections there certainly is reason for thinking that the red Catskill continental facies which closed the Devonian grades over into the succeeding non-red Pocono sandstones and conglomerates which mark the beginning of Mississippian sedimentation. However, if the recent conclusions drawn from my studies in northeastern Pennsylvania be correct, there is, in that region at least, a reason for accepting the belief in a disconformable contact. In central Pennsylvania this relation is less easily demonstrated, largely because of the absence of distinguishing marks of the several subdivisions of the Catskill facies group. It is difficult to prove the non-existence of transitional strata, though the thickness of such "passage" beds be but small, not the hundreds of feet which some have consigned to this interregnum. In general, through south-central, central, northeastern and north-central Pennsylvania, it is possible to draw a fairly sharp line between the base of the Pocono gray and the top of the Catskill red sediments. Thus did Henry D. Rogers early separate his Vespertine (Pocono) from his Ponent (Catskill) series (177). But for subsequent doubting Thomases, his distinction, drawn from some of the keenest observations ever made in Pennsylvania geology, would be unquestioned today. However, let us leave the continental facies *pro tem.* and observe the marine sediments.

When we consider the Devonian-Mississippian contact among marine strata, we encounter a wholly different problem. Where, with the continental facies, our deductions are based almost wholly upon lithology and stratigraphic sequences, we have now the added help (or hindrance!) of paleontologic data. We are forced to choose between conflicting possibilities. In the northwestern counties marine Devonian and Mississippian rocks are in contact. The nature of that contact has long been an enigma. Caster (33, 34, 35) has done extensive paleontologic research here for some years. His studies of old collections and interpretation of those he himself amassed have supplied data hitherto lacking or unappreciated for solving this problem. Upon the evidence of the organic remains and the physical data of the stratigraphic sequence, Caster writes (35):

> A minor disconformity separates the Knapp beds of the "Bradfordian," which are of Mississippian age, from the antecedent Conewango beds of Devonian age [see Table IV]. The faunas of the two divisions of the "Bradfordian series" offer very cogent arguments for such determinations of age . . . A study of the fossil faunas of the Knapp sequence clearly substantiates this age determination to the writer's mind. *Eumetria scansa*, three species of *Syringothyris* (in the strict sense), several species of the highly typical Lower Carboniferous gastropod *Igoceras*, as well as the interesting echinoid genera *Lepidesthes*, and *Hyattechinus*, and also several interesting crinoids would seem clearly to bespeak the Mississippian age of the Cussewago lower Mississippian monothem. None of these fossils is known from the underlying Conewango series, or, to the writer's knowledge, from the Devonian elsewhere.

I agree with this view in that I have recognized the Devonian-Mississippian disconformity among the continental formations in northeastern Pennsylvania. Traced westward, this appears to hold the identical stratigraphic position with that mentioned by Caster for the salt-water sequence. Comparison of Tables II and IV shows this, the Mount Pleasant red shale pinching out between the Pocono (Mississippian) and Elk Mountain (Devonian) sandstones. Since the Elk

Mountain is correlated with Oswayo, and the basal part of the Pocono probably ties in with the Knapp, the unconformities recognized by Caster and me (248) in the marine and continental facies respectively are essentially contemporaneous. There is, nevertheless, some ground for considering certain of the shaly beds in some of the marine sections to be transitional, and the final word is yet to be given on all the continental sequences.

Lower limit. The base of the Devonian in Pennsylvania has been variously defined and has received sundry usages since the appearance of Rogers's immortal "Geology of Pennsylvania" in 1858. In Vol. II, page 750, he wrote:

> Between the Silurian and the Devonian equivalents there is a much less abrupt plane of separation than the one which divides the Silurian from the Cambrian [the term Ordovician was of course not in use at that time]: that is to say, there exists a greater relative interchange of fossils, and with it, in many districts, a closer blending of the sedimentary deposits than we discern crossing the other platform below. This causes, indeed, some ambiguity in the determination of a proper horizon for provisionally separating the Devonian from the Silurian. Guided by the general facies of the fossils—the Mollusca especially—the Meridian of the Oriskany sandstone is regarded by some palaeontologists, on the original suggestion of M. de Verneuil, as the base of the Appalachian-Devonian deposits; while other naturalists incline to begin the Devonian period at the commencement of the Post-Meridian shales and limestones which overlie or succeed that rock.

Lesley, 1892, in summing up the work of the Second Survey (137), amplified Rogers's remarks:

> The hard and fast line which has been drawn between Silurian and Devonian on the other side of the Atlantic where disturbances (elevation and erosion) had occurred was looked for on this side of the Atlantic and thought to be found at Formation No. VII [Oriskany]. Some, however, drew the line at the top of No. VII, and the others at the bottom; so that there has continued to be to the present time a difference of opinion between those who assign the limestone formation No. VI [Helderberg] to the last hour of the Silurian day, and those who prefer to make the Devonian age begin with the limestone deposits at the bottom of No. VIII [Middle and Upper Devonian]. The discussion is a futile one. Were it possible to answer the question when did the Silurian age end, the answer would be barren of all utility. Such questions are of no importance whatever; and in fact, like many discussions in other branches of human knowledge, they originate not in facts but in prejudices and confuse instead of enlighten the mind. It would be a happiness for all conscientious field workers in geology if these names Devonian and Silurian could be remitted to oblivion. Time and thought have been wasted in drawing across the great column of the rocks lines which nature ignores and the science of geology should repudiate.
>
> In Pennsylvania it [the Oriskany] is an important formation, as will be seen in the chapter devoted to it; but it is so varied in its composition, and absent in so many places, that nothing but a slavish subserviency to the English nomenclature can explain the importance assigned to it as a division mark between two ages of geological time. Paleontologists once thought and had no hesitation in saying that the whole world of created life came to an end at Formation VII, and that a new world was created entirely different from the preceding world. But the progress of that branch of geology has modified the sentiment; and it is doubtful now whether a greater fossil break occurs between Upper Silurian and Devonian than at any other stage in the development of animal forms. At all events we cannot submit our classification of the mechanical deposits which proceeded without interruption in a water basin as vastly extended as the

> Appalachian ocean to the dictum of observers who busy themselves exclusively with nice distinctions of species and genera in animal forms; forms which in spite of these distinctions are essentially the same. We may therefore dismiss with these remarks the whole question of Silurian and Devonian; although for convenience sake the words Silurian and Devonian will always be in use, and can always be safely used if their vagueness be kept in view, and no theoretical conclusions opposed to facts be drawn from them.

Today the New York Survey draws the base of the Devonian between the Coeymans limestone, which it places in the base of the Helderbergian, and the upper Manlius (Keyser) which it considers highest Silurian (104, 105). The New Jersey Survey has done likewise (140, 223), calling the Coeymans the basal Devonian. The geologists of the Maryland Survey, on the other hand, have drawn the base of the Devonian between the Tonoloway limestone below and the Keyser limestone above (142, 204, 205). This usage is based upon comparison with the Bohemian succession. Schuchert (205) says (pp. 76-77):

> In 1900 the writer compared the Konieprusian fauna with that of the Helderberg and found the two to be very similar, in fact parts of one faunal realm. He also found that both appear to represent the oldest Devonian life. Close resemblances are seen among the brachiopods and the most important Helderberg forms have direct equivalents in the Konieprusian. In his paper on the Lower Devonic Aspect of the Lower Helderberg and Oriskany formations, he stated: "Each region has, of course, its own development, and the common forms of one region may be rare in the other. For instance, in America the great development . . . of Dalmanella and Rhipidomella" has but little variation in the Konieprusian, "while here the spire-bearing families Meristellidae and Athyridae have a far greater diversity. The same is also true for the Rhynchonellidae, although these shells are varied and abundant in the Lower Helderberg . . . The great diversity of the fenestelloids" in the Konieprusian "is in harmony with a similar development in the New Scotland. The stromatoporoids are also in harmony with this view. The trilobites do not oppose this correlation, but two characteristic species of the Lower Helderberg—*Dalmanites micrurus* and *Acidaspis tuberculata*—find their equivalents in the next higher zone, or G . . . The writer therefore concludes that the Konieprusian (F_2) and the Lower Helderberg are the equivalents of each other and represent the best known lowest Lower Devonian faunas."

In 1918 J. B. Reeside (167) applied this usage to the Helderberg of central Pennsylvania. By drawing the Silurian-Devonian line between the Keyser and the Tonoloway limestones, he raised to intersystemic importance what I. C. White had considered a minor break between his "Stormville" and "Bastard" limestones and subjacent "Bossardsville" (228) limestone. White in 1883 (229) had drawn the Devonian-Silurian boundary at the top of the Oriskany. This usage, considering White's ability as the outstanding stratigrapher of the Second Survey, is not to be scorned. The subsequent exhaustive studies of our Silurian and the Helderberg by Frank M. Swartz followed at first the Maryland usage and amplified Reeside's work in Pennsylvania (207, 208). Swartz formerly drew the basal Devonian between the Tonoloway "ribbon" limestone and the succeeding Keyser limestone, lowest member of the Helderberg group as formerly used. Since direct tracing between Maryland and central Pennsylvania is possible there can be no question as to the accuracy of his north-south correlation. Swartz has carried his correlations completely across Pennsylvania into New Jersey. His most recent work, however, has led him to draw the Silurian-Devonian boundary between the Keyser and Coeymans. This agrees with the work of the New York stratigraphers and seems more in harmony with recent interpretations of the European sequence (Cf. Allan 1). Observations by Cleaves recorded in Chapter III substantiate Swartz's ideas. Chapter II, contributed by Professor Swartz, describes fully his present interpretation of the interesting Helderberg group and its relations to underlying strata. Further discussion of the Silurian-Devonian relations is therefore postponed to Chapter II.

PHYSIOGRAPHIC EXPRESSION

The Devonian formations of Pennsylvania, unlike our Silurian, Mississippian and Pennsylvanian, include no elements which are consistently prominent ridge makers save in quite restricted portions of the State (8, 9). Among the Catskill units, the Honesdale sandstone together with the Pimple Hill conglomerate of the Cherry Ridge red beds comes nearest to being an exception to this statement. It is chiefly the Honesdale which forms the escarpment of the Pocono Plateau, a feature analogous to the Allegheny Front, which, however, is supported by the younger, Pocono formation. From the Plateau southeastward, the Honesdale and Pimple Hill give rise to the southern of the two crests of Second Mountain. Its northern crest is the Pocono and the intervening valley is floored with Cherry Ridge and (or) later red beds. The Devonian ridge dwindles toward the Susquehanna. It flanks Cove Mountain and is called Pine Ridge in Perry County and recrosses the river at Clarks Ferry. Thence east, though Honesdale and Pimple Hill lithologies may sometimes be observed, the topographic expression is merely a bench along the north side of Peters Mountain, until eventually it dies out eastward. Along the Allegheny Front, the Catskill contains certain conglomerates or hard, pebbly sandstones which are productive of slight ridges or benches concentric or parallel to the main escarpment. Among the other Catskill continental units is the Elk Mountain sandstone, a member whose lithology closely resembles the Honesdale, but whose distribution is confined to the northeastern counties. It is slightly younger and usually much thinner than the Honesdale and tends to produce a terrace or bench concentric to the outer rim of the Lackawanna basin which is delineated by the Moosic Mountains and their equivalents.

In the Susquehanna and Juniata valleys of central Pennsylvania north of Harrisburg, the Hamilton group is dominated by the Montebello sandstone, a hard, pebbly rock 800 to 1,000 feet thick above the first water gap on the Susquehanna but thinning rapidly to the north, east and west. This underlies such features as Half Falls Mountain, Little Mountain and a few lesser ridges, chiefly in Perry County. The Marcellus carries local sandstones in this same general region. One of these takes its name from Turkey Ridge which it upholds along the south side of Juniata County. In south-central Pennsylvania another sandstone, the Chaneysville member, quite distinct from the Montebello, appears in the midst of the Mahantango formation and forms small, local ridges.

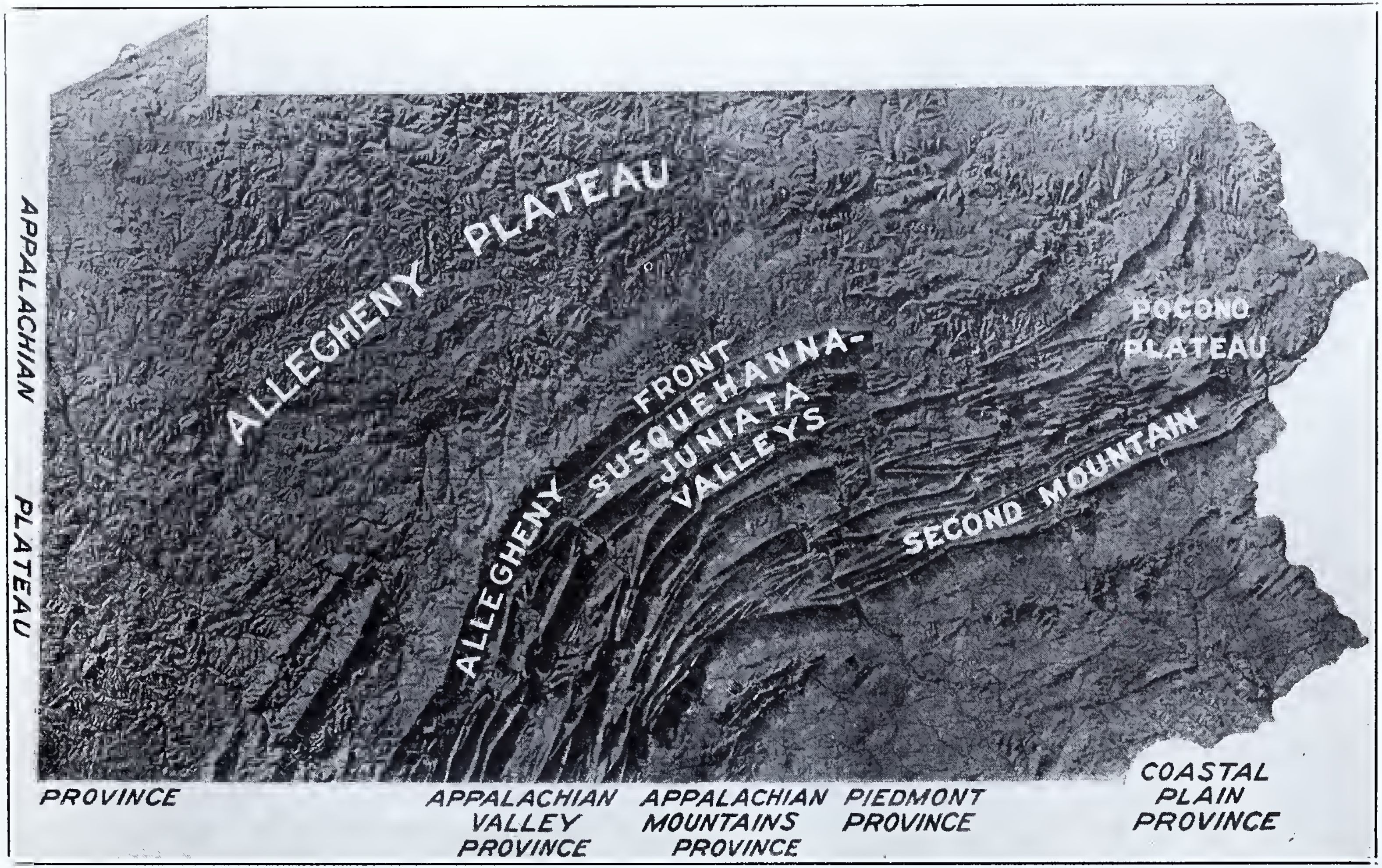

Figure 6. **Relief Map of Pennsylvania.**

The Portage group from the Susquehanna Valley between Sunbury and Harrisburg and eastward to the Delaware consists mostly of the hard, flaggy Trimmers Rock sandstone. This 1,000 to 1,600 foot unit produces small ridges in the more intensely folded portions of the Appalachian Valley. It becomes the major ridge-forming Devonian element in the Susquehanna-Juniata valleys as the Montebello sandstone of the Hamilton is displaced by Mahantango shale. In the east, where folding is less, the Trimmers Rock sandstone, though thinner, produces a well-defined scarp in the Delaware Valley It passes northeastward into the non-marine Delaware River flags which has a similar tendency to form low prominences, chiefly in Pike and Monroe counties.

Despite the fact that it consists often of coarse sandstone to "pea" conglomerate, the Oriskany is paradoxically a poor ridge-maker. In Monroe County it might be mistaken for the supporting element of Godfrey Ridge, but actually the locally well-developed Espus "grit" holds up this feature. Probably the reason for the Oriskany's not appearing oftener as a ridge is the characteristic weakness of the cement, which may be ferruginous or calcareous, but even the cherty phase tends to break up rapidly. To be sure, there are such exceptions as Warrior Ridge in Huntingdon County, composed of Oriskany sandstone. The Oriskany makes other, less prominent ridges southward in Bedford and Fulton counties. Conversely, in Northumberland, Montour, Columbia and parts of adjoining counties, we have the anomalous condition of low ridges supported by the Helderberg limestone, while the adjacent terrane underlain by the Oriskany is featureless. So poor are the exposures of the sandstone in this part of the State that it is locally doubtful if the Oriskany is actually present. At Palmerton the Palmerton sandstone and Bowmanstown chert and the Oriskany together support Stony Ridge.

By contrast with its minor ridge-forming elements, many of the major Devonian units habitually floor the valleys. This is characteristic of the Hamilton, Portage, and Chemung sandy shales. The Helderberg, often found along the valley sides flanking the rising ground adjacent to mountains of Silurian sandstones, may or may not form a low ridge. Among the units constituting the Catskill, the shalier members tend to form valleys parallel or concentric to the ridges of Pocono sandstone. In general the Devonian rocks of Pennsylvania do not tend to produce prominent topographic features. Rather, they chiefly form the lesser ridges and valleys which striate the Appalachian Valley section.

ECONOMIC ASPECT OF THE DEVONIAN

Of all the Paleozoic systems represented in Pennsylvania, none, save the Pennsylvanian, is today more productive of mineral wealth than the Devonian. It may be a paradise to the stratigrapher and paleontologist, but its economic aspect, except for petroleum and natural gas, is weak. This absence of abundant mineral deposits is doubtless the principal reason why the system has received so little attention in the past. It supplies natural gas, petroleum, silica, lime and a few other products in small amounts. A brief résumé of these resources follows.

Metallic Products

Iron ore. Occasionally we find reference to the discovery of small occurrences of lead and copper minerals in our Devonian rocks, but the only metalliferous product ever profitably mined from the system in Pennsylvania was iron. No longer mined, 50 to 100 years ago ferruginous beds in the Oriskany, Marcellus, Chemung and Catskill were worked. Iron ore seems also to have been taken from beds of Portage age. The known lenses of oölitic hematite in the Hamilton are of infinitesimal value. In general all the iron-bearing strata are too thin or the ore too lean to signify. Practically all the ore appears to be of the "bog iron" type. The limestones are not known to have contributed to the supply.

Paint ore (123, 146). In the Lehigh Valley near Palmerton in the midst of the Onondaga is a limestone bed rich in carbonate of iron. This has long been mined and burned as pigment, but actually is of comparatively small monetary value. In the past there seem to have been a number of these mines in this region to which this ore bed is probably confined.

Non-metallic Products

Coal. From the earliest days of geologic work in Pennsylvania, black shales and coal have been inseparable in the lay mind, though their dissociation in the field is as common as their juxtaposition. There are black shales of Devonian age, notably the persistent Marcellus, probably the most widespread, homogeneous formation in the system. The Burket and Harrell (collectively the "Genesee" of authors) are a close second in prominence to the Marcellus. These Devonian black shales are of marine origin; those of the Coal Measures are chiefly fresh-water formed. Devonian coal has been discovered in beds up to an inch thick, but in no way associated with black shales. As examples, there is an occurrence in the continental Catskill facies in Lycoming County in road cuts on State Highway 115 along Loyalsock Creek near Crooked Riffles Hollow. Here it is hard, shiny material which fractures readily at right angles to the bedding. In Pike County a little coaly material consisting of matted plant stems was observed in cuts on the U. S. Highway 6 northwest of Milford. Similar deposits have been found in other localities. Apparently, all are confined to continental deposits, and as such adumbrate the coal deposits of the Pennsylvanian. Locally, some of this Catskill "coal" may be replaced by copper minerals of no commercial value. (*Cf.* Butler, R. D., Econ. Geol., vol. 33, 1938, pp. 625-634.)

Flagstone. Brownstone fronts and flagstone sidewalks were inseparable features of our eastern cities fifty years ago. The former have gone out of fashion and our Triassic sandstone quarries are abandoned. Concrete and asphalt have so driven out flagstones that the quarries which pockmark the hills of northeastern Pennsylvania are mostly as deserted as the Triassic brownstone pits. Today, a little flagging is produced, largely for ornamental stone floors, but the days of flagstone sidewalks are gone to the limbo of the hitching post. Most of our flagstones came from the Catskill continental deposits in northeastern Pennsylvania. The New Milford sandstone was a great source of these slabs of gray-green, often delightfully ripple-marked sandstones. The Honesdale and Elk Mountain sandstones appear also to have been lesser contributors, and many abandoned quarries gape from exposures of the Delaware River flags.

Silica (88, 134). Sand excavation for the manufacture of glass has long been a thriving industry in Pennsylvania. A large part of this silica comes from the Oriskany sandstone (Ridgeley). Most of it is quarried in the region of Huntingdon at Mapleton, Everett, McVeytown, etc. In that part of the State, the Oriskany is nearly free from impurities and is easily worked, owing to the structure and lithology. In Monroe County there is found a white, impalpable powder referred to as "white clay". It is highly siliceous and has been mined for use in several industries. It is the product of weathering of either the New Scotland limestone or Bowmanstown chert or both.

Building and Crushed Stone (200). None of the Devonian formations is particularly attractive for building stone; few have also the requisite physical properties. Locally, some have been tried, including the heavier beds of the Helderberg limestones, the Oriskany, Montebello and Catskill sandstones. Crushed stone has been manufactured from some of our Devonian formations. The Helderberg supplies road metal. For this also the massive, eastern facies of the Onondaga has been used, but it is not particularly satisfactory, owing to the abundance of chert which breaks in sharp edges and points, ruinous to automobile tires. Only one quarry in the Tully is known to produce road metal. This is at Jersey Shore. Both the Montebello and Trimmers Rock sandstones have been crushed and used for highway construction. Some of their beds are very hard, dense and compact and of good quality for this purpose. Catskill members are sometimes crushed or merely broken by hand sledges in road work, particularly in our northern counties where these are almost the only source of hard rock.

Lime (147, 148). The Helderberg group has for years been a source of lime in Pennsylvania. It has been burned wherever the calcareous members of the group are well developed, provided better sources are lacking. The product is chiefly devoted to agricultural uses. The Onondaga has been burned to a less extent than the Helderberg and with indifferent success. It is either too cherty or too shaly to be of such commercial value that it can compete with the Helderberg. The Tully limestone has also been burned at a few places, but at present probably is not producing any lime. Ancient quarries and kilns are known in Bald Eagle Valley and Bedford County. When pure the limestone is usually quite thin; in thicker sections it is very shaly. Curiously, until the present researches were prosecuted, the unrecognized Tully was mapped as Helderberg with which it was confused. Such records as there may be of its use as a source of lime are consequently inseparable from accounts of the Helderberg. The Luthers Mills and other coquinites have been burned, principally in Bradford and Susquehanna counties, but are poor sources of lime. The only excuse for their use is the absence over large parts of northern Pennsylvania of true limestones. For additional information, see Chapter II on the Keyser and Helderberg beds which are quite calcareous.

Ground water (133, 141). In northwestern Pennsylvania where a large proportion of the surface and shallow rocks are of Devonian age, the following statement by R. M. Leggette regarding their value as aquifers is significant (133, p. 46):

> *Sandstones.* In northwestern Pennsylvania more than twenty distinct sandstone beds have been recognized. They are, with few exceptions, very irregular in character. Most of them are prominent only locally, but some of them are found over large areas. Even these beds of widespread occurrence are extremely variable in those characters that determine their water-bearing properties. It is, therefore, impossible to describe the water-bearing properties of any one sandstone. If a sandstone lies below the water table and is permeable, it may yield moderate supplies of water.
>
> *Shale.* Many of the domestic supplies of the area are obtained from shale. Although much of the shale has considerable porosity, the pores are so small that most of the water is retained in the rock and does not become available to wells. In many places, however, the shale is broken by joints along which water moves. Bedding planes also permit the storage and movement of water. Openings of this kind, if encountered below the water table, will supply small quantities of water, usually enough for domestic use. It seems probable that many of the wells reported by drillers as ending in shale or "slate," actually end in sandy shale. The commonly used terms "slate" and "shells" probably refer to thin-bedded sandstone.

Recent studies by Stanley W. Lohman are contained in two reports published by the Pennsylvania Topographic and Geologic Survey. The one covers northeastern Pennsylvania, the other the central and southcentral regions. Together with Leggette's bulletin just quoted, these embrace all of the important surface exposures of Devonian in Pennsylvania. Lohman's observations in northeastern Pennsylvania record the important Devonian water-bearing rocks to be of Helderberg age plus some of the Catskill sandstones. His records for south-central and central Pennsylvania indicate the Devonian strata most likely to yield water to be the Helderberg limestones, with smaller sources in the Oriskany, Hamilton, Chemung and Catskill sandstones (141).

Petroleum and Natural Gas (37, 38, 39, 40, 41, 89, 90, 92, 93, 94). Drilling for petroleum began in Pennsylvania in 1859. The early wells penetrated rocks of late Devonian age, the Conewango group, and are now rated among the oldest producing in the United States. For three-quarters of a century, petroleum has been obtained from such shallow sands as the First, Second and Third Venango. Deeper sources assignable to rocks probably nowhere older than the Chemung have also been tapped in this field. Below the Chemung is a great gap of barren Upper and Middle Devonian strata down to the Oriskany sandstone. Recent deep borings have reached the Oriskany in Tioga, Bradford and Potter counties particularly. In southwestern Pennsylvania some wells, though not many, which have penetrated the lower Devonian have been productive. Briefly, the highest Devonian formations in Pennsylvania have produced petroleum and natural gas, the lower Middle and particularly the Lower Devonian have yielded commercial flows of gas. Of the total petroleum produced in Pennsylvania, it is estimated that over 90 per cent has come from sands of Devonian age.

CHAPTER II

THE KEYSER LIMESTONE AND HELDERBERG GROUP

By Frank McKim Swartz
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INTRODUCTION

ORIGIN OF TERM HELDERBERG AND NAMING OF NEW YORK MEMBERS

The Helderberg Mountains, southwest of Albany, New York, make a bold escarpment, which rises abruptly from the Albany lowlands. The name was derived (104, p. 7) from the Dutch *helder,* bright, and *berg,* mountain, referring to the high limestone cliffs, which are conspicuous against the darker background of the wooded slopes.

The escarpment gave its name to rocks that are finely exposed along its face when the term Helderberg Division was introduced by Lardner Vanuxem in 1842 (218). Diagnostic fossil faunas of these and other New York sediments were studied by James Hall, and described in his classical volumes (112, etc.) on the Paleontology of New York. By these investigations, Hall laid the groundwork for correlations both in New York and other areas, and was largely responsible for the fact that the term Helderberg group, and many other names of New York origin, are extensively used through the Appalachian region.

In Hall's work, the limestones of the Helderberg Division of Vanuxem, with some emendations, were divided into Upper Helderberg, above the Oriskany sandstone, and Lower Helderberg, below it. The Lower Helderberg of Hall is approximately the Helderberg group of present terminology. The latter change in classification was proposed by Clarke and Schuchert in 1899 (69), when they advanced geographic names for New York formations, to replace lithologic and faunal terms of earlier usage. The classifications of Helderberg beds used by Hall and by Clarke and Schuchert are compared in Table VII, along with that followed by Goldring in a recent publication (105).

WORK IN PENNSYLVANIA BY FIRST AND SECOND SURVEYS

During the same developmental period, extensive geologic investigations were being carried on in Pennsylvania; first by Henry D. Rogers, whose First Annual Report was published in 1836, and later by members of the Second Geological Survey of Pennsylvania. The problems confronting these men differed in notable respects from those encountered by Hall in his studies of the fossiliferous rocks west of the Hudson River in New York. The sedimentary strata are much thicker in Pennsylvania. They underlie a larger and in part more rugged area. They have suffered more extensive deformation. Their economic products are more valuable. A larger proportion of the work consequently was devoted to studies of local structural and economic features.

The geologists of the Second Survey produced the very useful and, especially in terms of the date, very excellent series of areal geologic maps for the various counties. With these are many detailed and informative charts illustrating the geologic structures of important areas. Because of the magnitude of the problems, stratigraphic studies were rarely carried beyond a reconnaissance stage. The formations used in mapping were as a rule broadly conceived, and not well understood. The diagnostic fossil assemblages were little studied. Because of these deficiencies, many of the formational terms used by the Second Survey are today discarded.

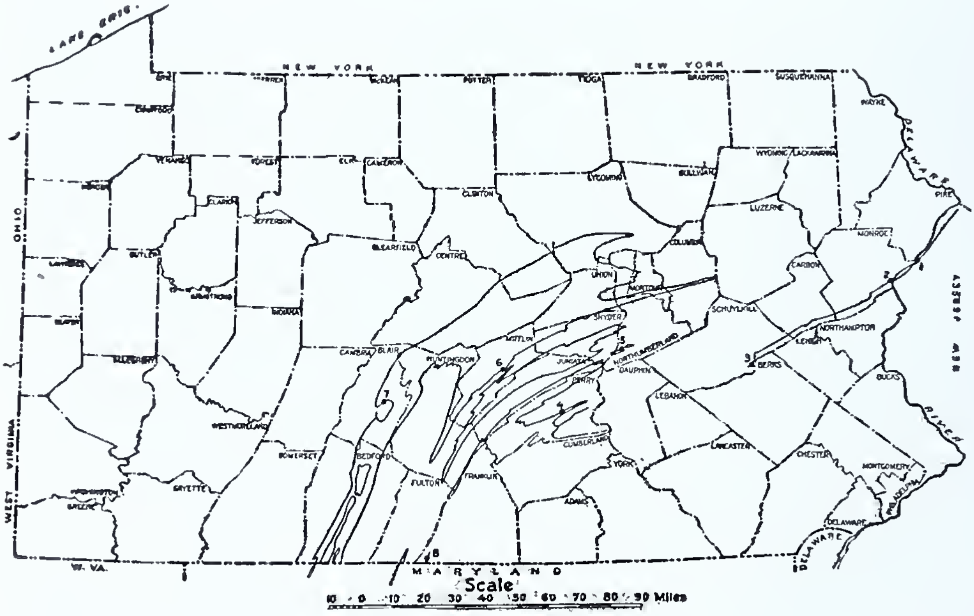


Figure 7. **Sketch map showing the distribution of the Keyser and Helderberg beds in Pennsylvania.**

1. Deckers Ferry, 2. Brodhead Creek, 3. Auburn, 4. Clarks Mill, 5. Mandata, 6. Mount Rock, 7. Hollidaysburg, 8. Warren Point.

The most notable work on Helderberg and Keyser beds was contributed by I. C. White (228, 229, 230) and E. W. Claypole (72). White presented a detailed and generally accurate account of these rocks as seen near Stroudsburg in eastern Pennsylvania (see Table VIII). His descriptions of equivalent beds in the central part of the State also are good, though his correlations are not wholly correct. Classifications used by White, Claypole, and some of their associates are illustrated in Table VIII.

INVESTIGATIONS IN NEW JERSEY AND MARYLAND

Limestones of Helderberg and Keyser age in northwestern New Jersey were described in 1903 by Stuart Weller (223, pp. 56-59, 62-94, 218-340). Weller followed Clarke and Schuchert and placed the base of the Helderberg group, and likewise the Siluro-Devonian boundary, at the base of the Coeymans limestone. The top of the Helderberg group was placed at the top of the "Kingston"—now Port Ewen—

TABLE VII

Classifications of Helderberg limestones in the Helderberg Mountain area of New York

		Hall, 1858			Clarke and Schuchert, 1899			Goldring, Berne Quad., 1935
Silurian		Oriskany sandstone	Devonian		Oriskany sandstone	Devonian		Oriskany sandstone; 6 feet
	Lower Helderberg Group	Upper *Pentamerus* and *Scutella* or Encrinal limestone		Helderberg Group	Port Ewen shale, south of Helderberg Mountain area proper. From Port Ewen, a village near Kingston, New York. (Name Kingston shale was used in 1899, but was preoccupied.)		Helderberg Group	Port Ewen (and Alsen?) limestone, 15 feet.
					Becraft limestone, from Becraft Mountain, near Hudson, New York.			Becraft limestone, 15 feet.
		Delthyris shaly limestone			New Scotland limestone, from New Scotland, a town in Albany County, New York.			New Scotland beds, 100 feet, including at base cherty Kalkberg limestone, 20 feet. Named from the Kalkberg, a limestone ridge near Catskill, New York, by Chadwick, 1908.
		Lower *Pentamerus* limestone			Coeymans limestone, from Coeymans, a town in Albany County, New York.			Coeymans limestone, 50 feet.
		Tentaculite limestone	Silurian		Manlius limestone, from Manlius, a town near Syracuse, New York.	Silurian		Manlius limestone, 45 feet.
	Waterlime group				Rondout limestone, from Rondout, a suburb of Kingston, New York.			Rondout limestone, 3 to 20 feet.
	Coralline limestone				Cobleskill limestone, from a tributary of Schoharie Creek.			Cobleskill limestone, 0 to 7 feet.

TABLE VIII

Comparisons of classifications of Keyser-Helderberg limestones used by members of the Second Geological Survey in Pennsylvania, and classification used in New Jersey.

	I. C. White				
Weller (223) New Jersey	Monroe County (228)	Dalmatia (229)	Mapleton (230)	Claypole Perry County (72)	D'Invilliers Lewistown (82)
Devonian	Dev.	Dev.	Dev.	D.	Dev.
Oriskany: "*Spirifer*" *murchisoni* zone	Oriskany sandstone	Oriskany sand-stone, chert	Oriskany sandstone	Oriskany ss	Oriskany sandstone
Orbiculoidea jervensis zone	Silurian	Silurian	Silurian	Silurian	Silurian
Dalmanites dentatus zone	Lower Helderberg	Lower Helderberg	Lower Helderberg	Lower Helderberg	Lewistown limestone
Helderberg group: Kingston (= Port Ewen) shale	(absent in part)	(absent in part)	Stormville shale	White flint	Lime
Becraft limestone	Stormville shale	Stormville shale	(absent in part)	(absent)	(absent in part)
New Scotland shale	Stormville congl.	Stormville limestone	Lime shale	Yellow flint shale	shale
Coeymans limestone	Stormville limestone	Bastard limestone	Massive limestone	Black cherty limestone	Massive limestone
Silurian: Manlius limestone	Stormville cement bed	Bossardville limestone		Clark's Mill shale	
Rondout limestone	Decker's Ferry limestone			Lewistown limestone	
Decker Ferry (= Decker) limestone	Decker's Ferry sandstone Decker's Ferry shale				
Bossardville limestone	Bossardville limestone				

shale. The next overlying beds, already known as the *Dalmanites dentatus* horizon through work by Barrett, were included in the basal part of the Oriskany, though their close relations to the underlying Helderberg were recognized.

Helderberg and associated limestones were also being investigated and described in western Maryland. In 1903 Charles Schuchert published a brief synopsis of work which had extended over several years (180). He recognized divisions for which he used the New York terms Salina, Manlius, Coeymans, New Scotland, and Becraft. In 1911 E. O. Ulrich and G. W. Stose visited western Maryland with C. K. Swartz, and agreed to divide these limestones into Helderberg limestone, of Lower Devonian age, above; and Tonoloway limestone, of Silurian age, below (213). The Manlius limestone of Schuchert, and most of his Coeymans limestone were placed together in a new member, included in the Helderberg formation, and named Keyser limestone from Keyser, West Virginia.

TABLE IX

Relations of Keyser-Helderberg limestones in western Maryland, as described in 1913 (142).

West of Hancock			East of Hancock		
Devonian	Oriskany	Ridgeley sandstone "*Spirifer*" *arenosus* fauna, 130-250 feet.	Devonian	Oriskany	Ridgeley sandstone '*S.*' *arenosus* fauna, 65 feet.
		Shriver chert, 100 feet.			(absent).
	Helderberg	(absent).		Helderberg	Becraft limestone "*Spirifer*" *concinnus* fauna, 85-125 feet.
		New Scotland shale and limestone, 50 feet.			New Scotland limestone, 25 feet.
		Coeymans limestone, 8 to 10 feet.			Coeymans sandstone, 10 feet.
		Keyser limestone, 270 to 290 feet.			Keyser limestone
Sil.		Tonoloway limestone	Sil.		Tonoloway limestone

A preliminary description of the Keyser and its faunas was contributed by Ulrich in 1912 in the Pawpaw-Hancock Folio of the U. S. Geological Survey (202). The Keyser was considered Devonian though older than the Coeymans because (1) it contains numerous species closely allied to those of the unquestioned Helderberg group; (2) work in progress led Ulrich to believe that the Keyser is intermediate in age between the Coeymans and typical Manlius, considered next older than the Coeymans by New York geologists. The Keyser was thus considered "an older stage of the Helderberg group than was known or recognized in New York."

Keyser-Helderberg sections at Keyser, West Virginia, and at numerous localities in western Maryland were described in 1913 by C. K. Swartz, T. P. Maynard, Charles Schuchert, and R. B. Rowe (205). The divisions and relationships recognized in the Lower Devonian in Maryland (142, 152, 182, 186, 205, etc.) are illustrated in Table IX. Correlation of the Maryland beds was discussed by C. K. Swartz (202). The Keyser was again considered part of the Helderberg group, because of the high percentage of Helderbergian species, and uncertainties concerning correlation with the New York formations. Swartz pointed out, however, the presence of a widespread disconformity separating the Keyser and Coeymans limestones.

RECENT WORK IN PENNSYLVANIA

In 1917, J. B. Reeside (167) described the Keyser-Helderberg rocks of part of central Pennsylvania. His work was especially concerned with the Keyser. It was found to duplicate closely the lithologic and faunal features that characterize it in western Maryland. In 1929, the writer (207) published results of studies tracing the Helderberg limestones from western Maryland into the Virginias, and also describing several Lower Devonian sections in central and eastern Pennsylvania (208). The classification used in Maryland was followed by both Reeside and the writer. Striking lateral changes occur in the sediments in the Virginias. Apparent interfingering of the southern continuation of the "Becraft" limestone and Shriver chert raised questions as to the relations of these beds, which are further considered in this paper.

ACKNOWLEDGMENTS

The writer has made use of Reesides excellent descriptions of Keyser-Helderberg sections at Tyrone, Mapleton, Clarks Mill, Dalmatia, Selinsgrove Junction, and Grovania, Central Pennsylvania. Several of these are included in somewhat abbreviated form in this paper, with suitable acknowledgments in each case, pointing out the extent to which Reeside's descriptions have been modified by the writer's work. Sections near Palmerton, Rausches, and Auburn in eastern Pennsylvania were studied by C. K. Swartz and the writer in connection with their investigations of the Silurian and early Devonian of that area. C. K. Swartz has also permitted use of data from sections studied by him near Andreas and Schuylkill Haven, and has made helpful suggestions concerning many of the problems discussed in this paper. Sections at Kunkletown, Falling Springs, and Neelyton were called to the writer's attention by A. B. Cleaves, who also visited localities in New Jersey and southeastern New York with the writer. The School of Mineral Industries of The Pennsylvania State College provided facilities for laboratory work. Under the writer's direction, F. M. Swain prepared photographs of fossils.

NEED FOR FURTHER STUDIES

The Keyser and Helderberg deposits of Pennsylvania need further study, both as to lithologic sequences and characteristic faunas. The present chapter is based on about four months of field and laboratory study during the summers of 1937 and 1938, with review of some previous work. At many of the new localities, only a small part of the collected faunas has been adequately worked up, especially in the case of the Keyser. Studies of late Helderberg and Oriskany ostracoda at localities from southeastern New York to Maryland are being carried out with help of a grant from the Penrose Bequest. Some work has been done with the profuse ostracoda in the Keyser in central Pennsylvania. A few preliminary statements referring to these studies are included in the present discussion.

CHARACTER AND CORRELATION OF THE KEYSER LIMESTONE AND HELDERBERG GROUP OF PENNSYLVANIA

The Keyser limestone and each of the formations of the Helderberg group will be discussed in order under the headings: general relations, surface distribution, members and lithologic features, boundaries, thickness, economic value, fauna, and correlation. A special section is devoted to the age of the Keyser and position of the Siluro-Devonian junction in the Appalachian area. The classification of Keyser and Helderberg beds used at this time is shown in Tables XIII and XIV.

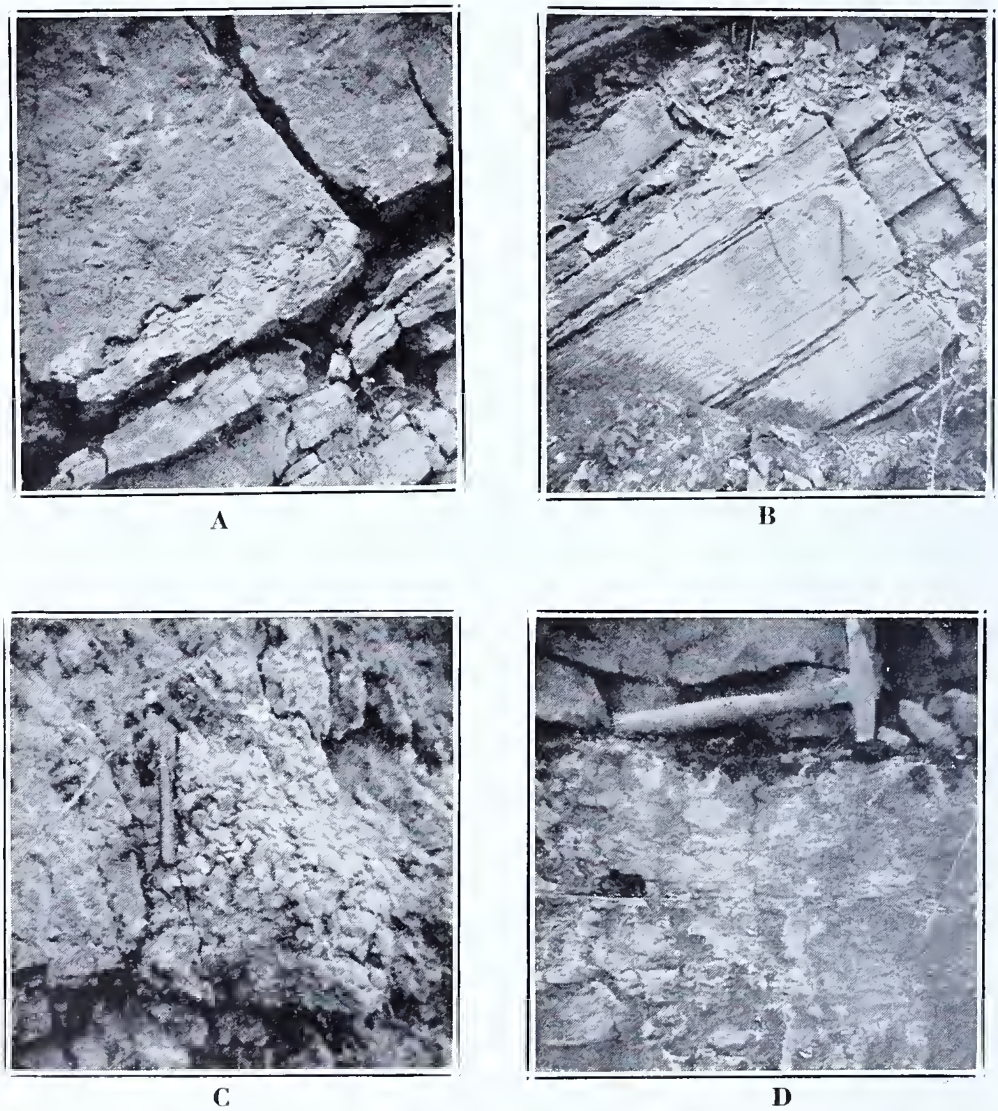
THE KEYSER LIMESTONE

General relations. At its type locality, Keyser, West Virginia, the Keyser limestone is 280 feet thick. The sequence there is:

Thin-bedded, in part laminated limestone	70 feet
Thick- and some thin-bedded limestone	145 feet
Thick-bedded lumpy limestone	65 feet

The fauna is dominated by brachiopods, but includes corals, cystids, bryozoa, mollusks, and some trilobites and ostracoda. The Keyser is overlain by Coeymans limestone, 12 feet thick, and containing the characteristic *Gypidula coeymanensis* fauna. Below it is the Tonoloway limestone, 590 feet thick, for the most part laminated and sparingly fossiliferous.

Surface distribution. The Keyser limestone extends northward from Maryland into central Pennsylvania, and is widely exposed through the Appalachian Ridge and Valley Province (Figure 7). It is faulted out for about 15 miles in eastern Fulton County. It is not known between southeastern Perry County and Schuylkill County. Disappearance of the Keyser and adjacent beds along the latter belt has been attributed to both faulting and unconformity. Near Auburn, in south-central Schuylkill County, 3 feet of Oriskany (?) is seen in contact with Bloomsburg red shale, without apparent evidence of faulting. In the writer's opinion, the increasing content of sand and pebbles observed in the Keyser, Helderberg, Oriskany, and Esopus beds in approaching Auburn from the east, strongly indicates that their disappearance here is due to a sedimentary break. Because of their absence in this interval, the Keyser-Helderberg beds of central and eastern Pennsylvania are entirely disconnected along their outcrop; but there is every reason to believe that they are continuous



Photographs by F. M. Swain

Figure 8. **Features of the Keyser limestone. *A.* Sharp and irregular, evidently disconformable contact between crystalline Coeymans limestone above, and dense limestone of upper Keyser below. *Gypidula* valves are weathered in relief on the Coeymans surface. Scale about as in C. Section near Painterville, Pennsylvania. *B.* Laminated limestone beds of upper part of Keyser limestone, Painterville, Pennsylvania. *C.* Lumpy limestone, lower part of Keyser limestone. Section one and one-half miles north of Selinsgrove Junction, Pennsylvania. *D.* Contact between dense, laminated Tonoloway limestone below, and finely crystalline basal Keyser above. North of Selinsgrove Junction.**

through northeastern Pennsylvania below the younger Devonian and Carboniferous. East of Auburn the outcrop of Keyser and equivalent beds extends across Pennsylvania, northwestern New Jersey, and part of the Hudson Valley, to the Helderberg Mountains southwest of Albany, New York.

Members and lithologic features. The three lithologic divisions of the Keyser at the type locality persist through much of central Pennsylvania. Their boundaries are variable in position, and generally fail to correspond to the most important faunal changes within the formation. Consequently, they are not named as members of the Keyser, even though their regional significance must be recognized.

The peculiar lumpy character of the lower Keyser is its most outstanding lithologic feature throughout western Maryland, central Pennsylvania, and much of the Virginias. In places the beds consist of small lumps or nodules of finely crystalline dark limestone, embedded in more argillaceous limestone (Figures 8C, 9D). Bedding surfaces are far apart and are obscured by the tendency of the lumps to break across them. The more argillaceous beds weather to loose rubbly masses.

Other beds contain less of the argillaceous material and weather gray. Though forming more solid masses, they, too, weather to irregular fragments independent of the bedding. Both varieties grade into purer, more clearly bedded, less lumpy limestone.

In Blair, Huntingdon, and Mifflin counties, bodies of very thick-bedded, coarsely crystalline, gray, more or less crinoidal, non-lumpy limestones are interbedded with the lower nodular beds. One such at Mapleton is 30 feet thick, and yields 98 percent calcium carbonate according to Reeside (167).

The basal 10 to 30 feet of the Keyser are frequently less lumpy than the next higher beds. Reeside (167) included these beds with the Tonoloway at Lewistown, Dalmatia, and Selinsgrove, though he placed them in the Keyser at Clarks Mill. They are here assigned to the Keyser because of their lack of lamination, their somewhat lumpy character, and to some extent because of their fauna.

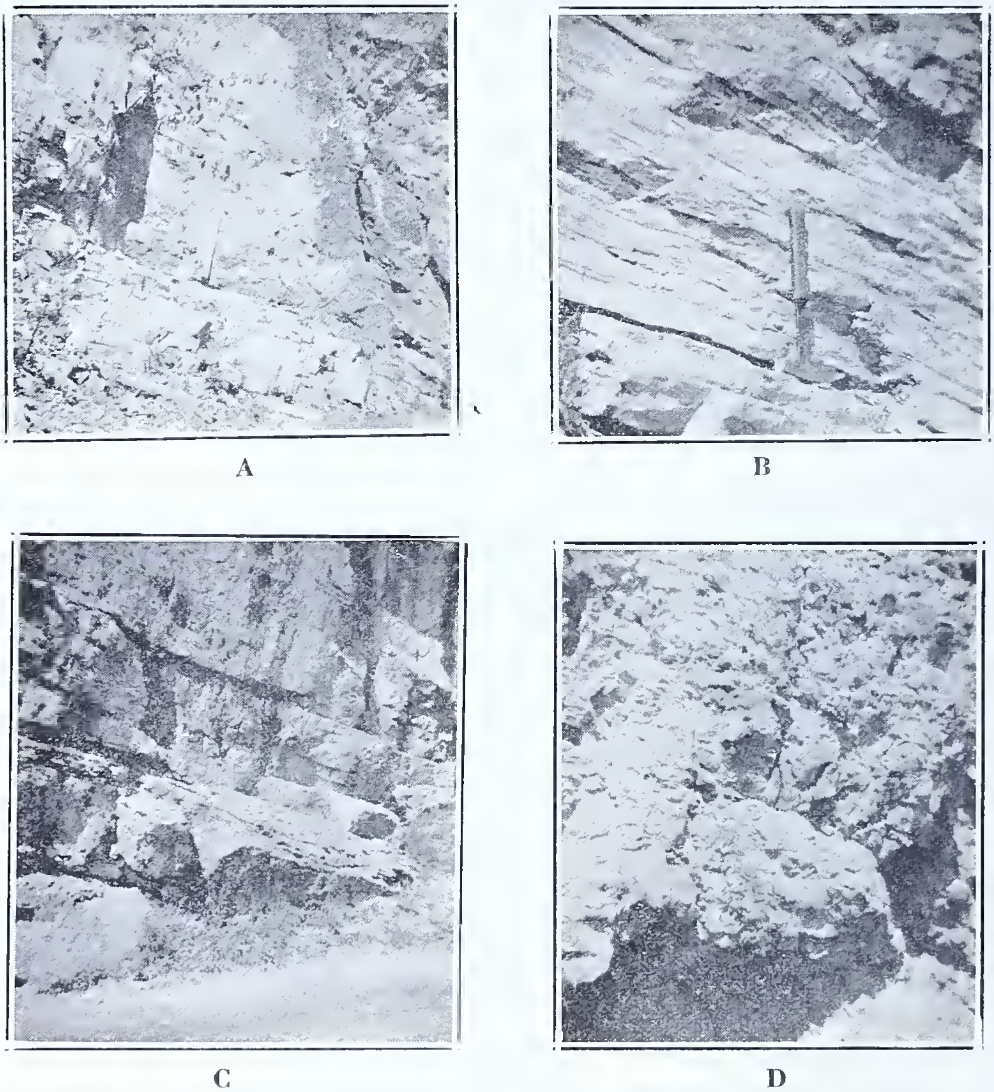
The laminated upper Keyser beds are commonly 25 to 50 feet thick in central Pennsylvania. In lithology and general paucity of fossils they tend to simulate the Tonoloway. These beds are less conspicuous toward Perry and Fulton Counties. Laminated beds also disappear southwards, in parts of the Virginias. In Fulton County some of the upper Keyser beds are a little lumpy, and the uppermost part resembles the Coeymans in lithology.

The Keyser of eastern Pennsylvania is lithologically unlike that of the central area. In eastern Monroe County the strata here included in the Keyser are as follows (See Figure 17):

Manlius limestone member: finely crystalline, thick-bedded, dark blue limestone, tending to weather to irregular fragments	30 feet
Rondout limestone member: thinly laminated limestone, including near top a seven foot bed of silty magnesian limestone, called the "peth stone" bed by Cook	25 feet
Decker sandstone member: thick-bedded calcareous sandstone and some limestone	60-90 feet

The lower member was named "Decker's Ferry sandstone" by I. C. White (228). White used "Decker's Ferry" for several bodies of rock; but the U. S. Geological Survey has restricted the name to Decker limestone in New Jersey. (See Tables VIII, XII.)

There is a progressive increase in the proportion of clastic material in the Keyser beds, from the Nearpass quarries in New Jersey, where detrital material is inconspicuous; to Monroe County, where the Decker is arenaceous and in part pebbly; then to Palmerton and An-



Photographs by F. M. Swain

Figure 9. **Additional Keyser and Helderberg features. *A.* Contact between thick-bedded, gray, crystalline Coeymans limestone above, and laminated, dense limestones of upper Keyser below. *B.* Thin-bedded limestone with chert lenses, about fifty feet above base of Keyser. *C.* Thick-bedded limestone, about twenty to thirty-five feet above base of Keyser; lumpy limestone at base. *D.* Lumpy limestone about twenty feet above base of Keyser, scale about as in *B.* All from section one-half mile east of Hollidaysburg, Pennsylvania.**

dreas, Carbon County, where the Keyser is sandy throughout. At Andreas the upper Keyser is believed to be represented in part by red sandstone and shale.

The Keyser thins from Palmerton to Schuylkill Haven, Schuylkill County. The increase in clastic material in the Keyser, followed by thinning, and the similar changes that occur in the Helderberg, Oriskany, and Esopus beds, strongly favor the view that disappearance of equivalent deposits west of Auburn is due to unconformity and not wholly to faulting. (See Figures 10, 17.)

Boundaries. Through central Pennsylvania the Keyser is underlain by Tonoloway limestone; in the east it rests upon Bossardsville limestone, believed to be Tonoloway in age. Through virtually all its outcrops, it is overlain by Coeymans limestone and sandstone.

In central and south-central Pennsylvania, the base of the Keyser has been placed at the top of the thinly laminated limestones of the upper Tonoloway. The boundary is usually distinct; occasionally it is so sharp as to suggest an unconformity (see Figure 8D). In the east, the base of the Decker sandstone member is generally well marked.

Through central Pennsylvania there is an abrupt boundary between the dense, more or less laminated limestones of the upper Keyser, and the overlying thick-bedded coarsely crystalline Coeymans. The contact surface is somewhat irregular. Fragments of the dense limestone occur in the basal part of the Coeymans, generally accompanied by some arenaceous material. The contact is clearly disconformable in this area (see Figures 8A, 9A). In Monroe County, the junction of the Coeymans and the Manlius member of the Keyser is less well defined, and the break in sedimentation less clearly shown.

Thickness. Figure 10 illustrates the known variations in thickness of the Keyser limestone in Pennsylvania and adjacent areas to the north. The isopachs are generalized. The greatest known thickness, 290 feet, is found at Corriganville, near Cumberland, Maryland. An axis of maximum deposition, but not necessarily of deepest water, extends from western Maryland into central Pennsylvania and broadens between Jersey Shore and Selinsgrove. The Keyser thins westward to 100 feet near Tyrone; northeastward to 135 feet near Bloomsburg. The absence between Schuylkill and Perry Counties of the Keyser, together with the Helderberg, Oriskany and Esopus (?), is attributed to an irregularity of the ancient coast lines, here named the Auburn Promontory (Figure 10).* In the east, the Keyser or its correlates thicken to about 125 feet in New Jersey; thin to about 50 feet near Catskill, New York, on the flank of the Adirondack dome; thicken again westward to about 130 feet near Manlius, New York; then die away to 5 feet near Buffalo. Thinning against the Adirondack dome divides the New York deposits into two bodies, for which the terms New Jersey and Manlius lobes are here proposed.

Lateral changes in the sediments indicate that land lay to the south and east of the main Keyser basin. The increasing percentage of marine forms toward the south into Maryland and the Virginias, led C. K. Swartz (204, 205), J. B. Reeside (167), and the writer (207,

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* This statement is intended to apply primarily to the eastern portion of the area. In Dauphin and Perry counties the structure may be complicated by strike faults.

208) to conclude that the marine waters must have entered from that direction. In view of the lack of known Keyser faunas in the continental interior, however, the Manlius or New Jersey lobe may possibly have served as an oceanic channel.

Economic value. The Keyser and associated Coeymans and Tonoloway limestones are quarried at numerous localities along the belts of outcrop shown in Figure 7. These limestones are used principally for agricultural lime and road material (147, 148). They are generally not pure enough to be used for chemical lime in competition with the Ordovician limestone extensively quarried in central and eastern Pennsylvania. They are also less valuable as building stone.

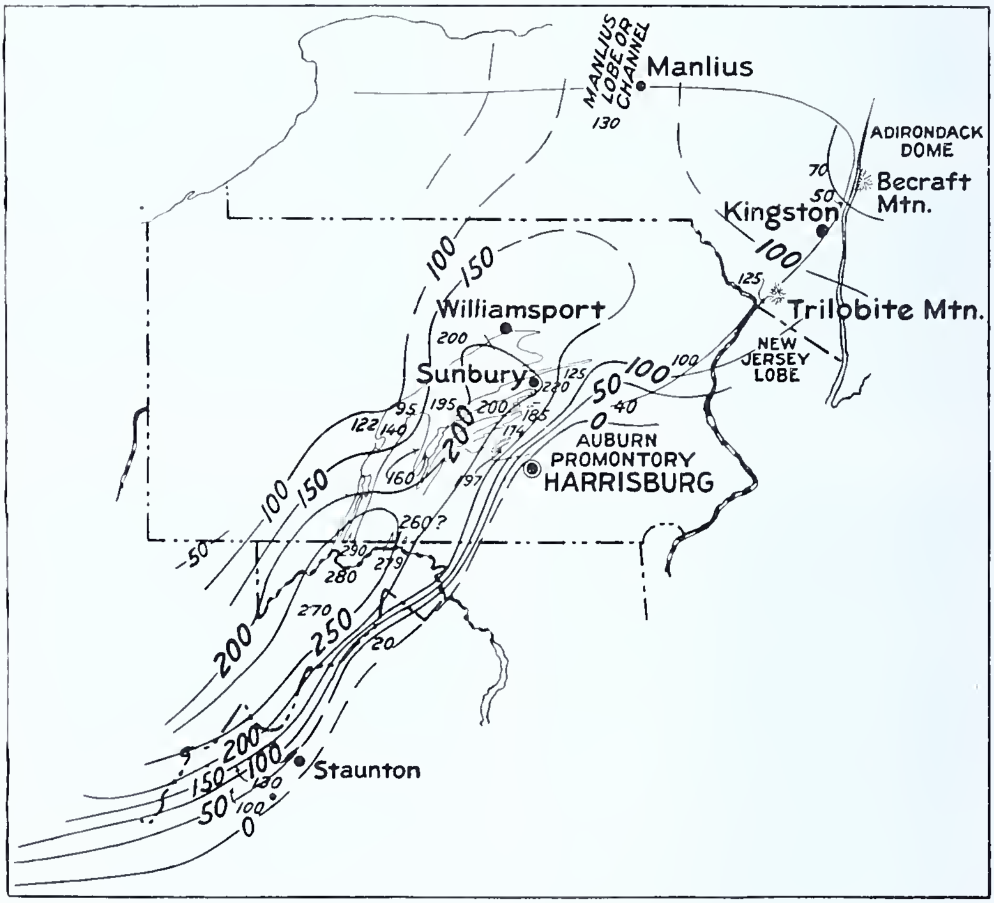


Figure 10. **Sketch map showing known variations of thickness of the Keyser limestone in Pennsylvania and of its supposed equivalents in New Jersey and New York. Isopachous interval fifty feet.**

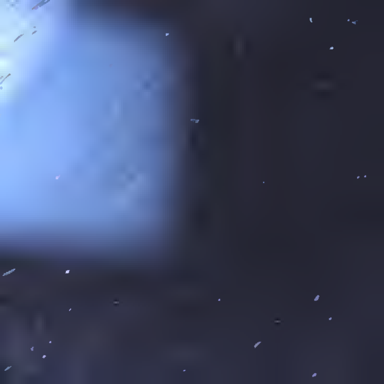
The Tonoloway limestone—or, in eastern Pennsylvania, the Bossardsville—is more commonly used as the quarry bed, because of its generally greater purity. In some regions, however, the lower Keyser is fairly pure, as at the large quarry at Mapleton, and these and higher beds are extensively quarried.

TABLE X

Faunal zones and subzones of the Keyser limestone

Pennsylvania	Maryland	West Virginia-Virginia
	Favosites helderbergiae var. *praecedens* zone	
17. *Leperditia* subzone	14. *Leperditia* subzone 13. *Stromatopora* reef	14. "*Spirifer*" *vanuxemi* var. *prognosticus* and *Whitfieldella prosseri* subzone
16. *Tentaculites* subzone 15. *Stromatopora* reef 14. *Rensselaeria mutabilis* subzone	12. *Tentaculites* subzone 11. Lower *Stromatopora* reef 10. *Rensselaeria mutabilis* subzone	*Camarotoechia* cf. *C. altiplicata* and *Nucleospira ventricosa* subzone 13. *Tentaculites* subzone 11. *Rensselaeria mutabilis* subzone
13. *Pholidops ovata* subzone 12. Lower *Leperditia* subzone 11. Coral subzone B. 10. "*Spirifer*" *vanuxemi* var. subzone	9. Keyser coral reef	10. *Meristella praenuntia* subzone 9. Petersburg *Stromatopora* reef 8. Coral subzone, with *Cladopora rectilineata*
	Chonetes jerseyensis zone	
9. *Calymene camerata* subzone 8. Bryozoan subzone	8. Bryozoan subzone	7. Bryozoan subzone 6. *Merista typa* subzone 5. *Camarotoechia gigantea* subzone
7. *Gypidula coeymanensis* var. subzone	7. *Gypidula coeymanensis* var. subzone	4. *Gypidula coeymanensis* var. subzone
6. *Dalmanella clarki* subzone 5. "*Spirifer*" *modestus* subzone 4. *Stomatopora* subzone 3. Coral subzone A 2. *Rhynchospira* subzone	6. Cystid—"*Spirifer*" subzone 5. Rawlings *Stromatopora* reef 4. *Cladopora rectilineata* subzone 2, 3. *Rhynchospira* subzones	3. *Stenochisma deckerensis*, "*Spirifer*" *modestus*, *Uncinulus convexorus*, and *Nucleospira swartzi* subzones 2. *Cyphotrypa corrugata* and *Stropheodonta bipartita* subzones (with *Rhynchospira globosa?*)
1. *Camarotoechia lamellata* subzone	1. Warrior Mountain coral reef	1. *Whitfieldella minuta* subzone

N. B. Quotation marks are used about the name *"Spirifer"* throughout this Bulletin. This has been done at the suggestion of Dr. G. Arthur Cooper, who advised it because of the present status of the classification of the "spirifers" and the prospect of sweeping changes in the group.



The closest approach to a more satisfactory zonal species for the upper Keyser is *Meristella praenuntia*. However, the range of this species is also considerably affected by ecologic relationships. As now understood, the upper Keyser is primarily a zone above the range of *Chonetes jerseyensis*, and below the Coeymans limestone.

The top of the *Chonetes jerseyensis* zone occurs about at the top of the lumpy beds of the lower Keyser at Selinsgrove and Lewistown. It more generally lies within the middle limestones that are neither lumpy nor laminated, as at Keyser, West Virginia. At some localities, mostly south of Pennsylvania, somewhat lumpy beds continue above the top of the zone.

The Decker sandstone member of the Keyser of eastern Pennsylvania contains the *Chonetes jerseyensis, Stenochisma deckerensis* fauna seen in the lower Keyser farther west. Faunas have not been observed in the uppermost beds of the sandstone. The more distinctive species of the upper Keyser of central Pennsylvania have not been observed in the Manlius and Rondout of Monroe County. Unfortunately, the faunas of these beds have not been studied in the laboratory. From field observations, the Manlius contains *Stropheodonta varistriata, "Spirifer" vanuxemi, Tentaculites gyracanthus,* as it does in New Jersey. The only fossils seen in the Rondout were unidentified *Leperditias*. In central Pennsylvania *"Spirifer" vanuxemi* and *Tentaculites gyracanthus* are most abundant in the upper Keyser; but also occur, though less commonly, in lower beds. *Stropheodonta varistriata* has not been identified in the upper Keyser in central Pennsylvania. The faunas do not provide wholly satisfactory evidence of the equivalence of the upper Keyser of central Pennsylvania and the Manlius and Rondout of Monroe County. However, the Manlius and Rondout lie above the *Chonetes jerseyensis, Stenochisma deckerensis* fauna of the lower Keyser, and are overlain by the Coeymans limestone, which likewise rests upon the top of the Keyser farther west. The essential late Keyser age of the Manlius and Rondout of Monroe County consequently seems to be assured.

Correlation with Maryland and the Virginias. The Keyser limestone is continuous along a series of outcrop belts from western Maryland into both central Pennsylvania and the Virginias. Close equivalence of the Keyser beds in these areas is further shown by relationships of the lithologic divisions, and especially by persistence of many faunal zones, as illustrated in Table X. Such changes as occur in central Pennsylvania appear to be lateral variations in contemporaneous sediments, and do not seem to be due to appreciable changes in age. The *Leperditia scalaris* subzone of the basal Keyser of central Pennsylvania is a possible exception. Its relation to the basal Keyser of Maryland has not been determined; though it occurs in these beds near Bedford, about 20 miles north of the Maryland line. Furthermore, the writer recently obtained *L. scalaris* 22 feet above the base of the Keyser limestone in the type section at Keyser, West Virginia.

Correlation with New Jersey. Except for change of the Decker from calcareous sandstone to limestone, the Manlius, Rondout, and Decker of the Nearpass quarries in New Jersey are closely similar to the Manlius, Rondout, and Decker of Monroe County in thickness, lithology, faunas, and relations to one another and to the underlying Bossardsville and overlying Coeymans. Correlations of the beds in these areas were described in part by White in 1882 (228), and by Weller in 1903 (223).

Many species characteristic of the lower Keyser of central Pennsylvania were first described from the Decker of New Jersey by Weller. Close equivalence is shown both by the general faunas, and by similarity of the faunal zones of the lower Keyser of central Pennsylvania, and those established in the Decker by Weller. Correlation of the Rondout and Manlius of New Jersey and the upper Keyser of central Pennsylvania is based on the same considerations used for correlation of the Rondout and Manlius of Monroe County, as previously discussed.

Correlation with central New York. Views concerning the correlation of the Keyser with beds lying below the Coeymans limestone in central New York, have involved questions concerning the relationships of the Manlius, Rondout, and Decker of New Jersey with the central New York deposits. Since 1912, there has been general agreement that the Keyser of Maryland and adjacent areas is essentially equivalent to these New Jersey beds. On the other hand, there have been marked differences in opinion concerning correlation of the Keyser and its New Jersey representatives with the Cobleskill to Manlius, which similarly lie below the Coeymans limestone in New York west of the Helderberg Mountain area. The principal differences in opinion are illustrated in Tables XI and XII.

As will be seen, both Weller (223) and Hartnagel (120, 121) correlate at least part of the Decker of New Jersey with the type Cobleskill of the Schoharie Valley, even though there are some differences in details. In 1912, on the other hand, Ulrich presented a widely different conception of these relationships (202, 214). He reported that Cobleskill faunas occur in the Tonoloway of Maryland, and that field studies in New York at that time indicated that the Keyser-Decker beds are represented at the top of the Manlius near Manlius, New York. According to this view, the typical part of the Manlius, the Rondout of authors, and the type Cobleskill of central New York are older than the Decker-Keyser beds in New Jersey and Maryland.

According to the studies of Weller (223), Hartnagel (120, 121, 122), Grabau (107), and others, the Decker and supposed Manlius of New Jersey and nearby parts of New York, on the one hand, and the type Cobleskill and type Manlius of central New York on the other, possess a marked faunal agreement. Hartnagel believes that the Manlius is traceable along the outcrop from the one area to the other, although the Cobleskill-Decker and much or all of the Rondout disappear by unconformity for some distance south of the Helderberg Mountain.

Two results of the writer's work in central Pennsylvania are of interest in this connection. The first is the widespread occurrence of the Cobleskill ostracode, *Leperditia scalaris,* in the basal part of the Keyser in Pennsylvania. The second is the marked reduction in the Tonoloway faunas as this formation is traced from Maryland

TABLE XI

Comparison of correlations of Decker, Rondout, and Manlius limestones

Weller, 1903			Hartnagel, 1903 and 1905		
Schoharie Valley, N. Y.	Kingston, N. Y.	Nearpass Quarries, N. J.	Nearpass Quarries, N. J.	Kingston, N. Y.	Schoharie Valley, N. Y.
Coeymans ls.	Coeymans ls.	Coeymans ls.	Coeymans ls.	Coeymans ls.	Coeymans ls.
Manlius ls.	Manlius ls.	Manlius ls.	Manlius ls.	Manlius ls.	Manlius ls.
(Rondout ls.)	Rondout ls. (restricted)	Rondout ls.	Rondout ls.	Rondout ls.	Rondout ls.
Coralline (= Cobleskill) ls.	Intermediate beds	Decker Ferry ls.: *Stenochisma lamellata* zone	Cobleskill ls.	Cobleskill ls.	Cobleskill ls.
		Pterodictya frondosa zone *Chonetes jerseyensis* zone	Decker Ferry ls. (restricted)	Rosendale ls. (= lower cement)	Salina
				Wilbur ls.	
Salina	Lower Cement beds (= Rosendale)	Bossardsville ls.	Bossardsville ls.		

TABLE XII

Correlation of Keyser limestone with New Jersey and New York beds

<table>
<tr><th colspan="6">Ulrich, 1912, 1913</th><th colspan="4">F. M. Swartz, 1938</th></tr>
<tr><th colspan="3">Manlius, N. Y.</th><th>Nearpass, N. J.</th><th colspan="2">Maryland</th><th colspan="2">Central Pa.</th><th>Nearpass, N. J.</th><th>Central N. Y.</th></tr>
<tr><td rowspan="4">Helderberg</td><td colspan="2">Coeymans ls.</td><td>Coeymans ls.</td><td colspan="2">Coeymans ls.</td><td colspan="2">Coeymans ls.</td><td>Coeymans ls.</td><td>Coeymans ls.</td></tr>
<tr><td rowspan="3">Keyser</td><td>Transition beds</td><td>“Manlius” of authors</td><td rowspan="3">Keyser ls.</td><td rowspan="2">Higher faunas</td><td rowspan="3">Keyser ls.</td><td rowspan="2">*Favosites praecedens* zone</td><td>Manlius ls.</td><td>Manlius ls.</td></tr>
<tr><td>Cement beds</td><td>Rondout ls.</td><td>Rondout ls.</td><td>Rondout ls.</td></tr>
<tr><td>Fossiliferous beds</td><td>Decker ls.</td><td>*Chonetes jerseyensis* fauna</td><td>*Chonetes jerseyensis* zone</td><td>Decker ls.</td><td>Cobleskill ls.</td></tr>
<tr><td colspan="3">Typical Manlius. and “Rondout” of authors
Cobleskill ls.</td><td>Bossardsville ls.</td><td colspan="2">Tonoloway ls.</td><td colspan="2">Tonoloway ls.</td><td>Bossardsville ls.</td><td>Salina</td></tr>
</table>

to the northern limit of its outcrop in Pennsylvania. Identification of the *L. scalaris* of Pennsylvania was confirmed by Goldring and Hartnagel, after comparison with New York specimens. Because of its peculiar dorsal hump, identification of this species is much more critical than for most members of the genus, and provides some added evidence favoring correlation of the lower Keyser and Cobleskill. The changes observed in the Tonoloway show that its faunas are becoming not more but less Cobleskill-like toward the north. On the other hand, conditions and faunas suggestive of the Cobleskill are more pronounced in the lower Keyser at Altoona, Tyrone, and Grovania, Pennsylvania, than in western Maryland.

The above relationships do not themselves provide conclusive evidence for correlation of the lower Keyser and Cobleskill. However, they support the other data favoring the essential contemporaneity of the Keyser of Maryland and Pennsylvania and the Cobleskill to Manlius of central New York. To the writer, this correlation seems highly plausible with the evidence now available.

Correlation with other areas. Distinctive Keyser faunas are not known outside of the Virginias, Maryland, Pennsylvania, New Jersey, and New York. Dunbar (83) suggested that the Rockhouse shale and basal part of the overlying Olive Hill formation of western Tennessee may be Keyser in age. The Rockhouse contains too poor a fauna for correlation, but the Olive Hill in part contains a well marked Coeymans fauna.

The distribution of faunas and sediments of the Keyser and its equivalents of the Appalachian area favors the view that the Keyser seas entered from the southwest. Absence of satisfactory Keyser faunas in the Rockhouse and other known sediments in that direction militates against this view; but it is difficult to see how the richer faunas of Maryland could have entered from the New York or New Jersey areas.

Age and Classification of the Keyser Limestone; Position of the Siluro-Devonian Boundary

The "Lower Helderberg" limestones of New York (see Table VII) were placed in the Silurian system by James Hall and other geologists of his day. On the basis of new understanding of the relations of Silurian and Devonian faunas in the classical regions of England, Germany, and the Bohemian basin, largely resulting from the labors of Beyrich, Kayser, and Frech, both Clarke (58; pp. 408-437) and Schuchert (69; pp. 241-332) concluded that the Helderberg fauna is not Silurian, but instead is early Devonian in age. The term, Helderberg group, was redefined, however, to comprise in New York only the beds from the Coeymans to the Port Ewen, inclusive.

Study of the rocks of Maryland led to further consideration of the problem. In describing the Helderberg limestone of the Pawpaw-Hancock quadrangles in 1912, Ulrich (202) suggested that the Keyser beds represent "an older stage of the Helderberg group than is known or recognized in New York". This view was based, first, on the occurrence in the Keyser of numerous species having distinct Helderbergian affinities; second, on the belief that, though older than the

Coeymans limestone, the Keyser is younger than the typical Manlius of central New York (see Table XII).

The Helderbergian affinities of the Keyser fauna are indeed pronounced; sufficiently so that, in 1903, Schuchert (180) was led to include in the Coeymans limestone the beds that later were made the *Favosites praecedens* zone of the Keyser of western Maryland. In 1913, C. K. Swartz (204) regarded 31 of the 164 known Keyser species, including 12 of the 36 species of the *F. praecedens* beds, as being definitely Helderbergian in their relationships. In view of the uncertainties concerning correlation of the Keyser and typical Manlius, raised by Ulrich's views, and following the principle that special weight must be given the younger members of a fauna, Swartz agreed that the Keyser should be considered a member of the Helderberg group and referred to the Devonian system. He pointed out, however, that the Keyser is really transitional between the Silurian and Devonian; that many of its species are derived from the Silurian, especially if the typical Manlius and Cobleskill are included in this category; and that the Keyser is separated from the Coeymans in Maryland by an abrupt lithological and faunal break and probable unconformity.

The Keyser was included in the Helderberg group and in the Devonian system on much the same basis by Reeside in studies in central Pennsylvania (167; pp. 118-120) and by the writer in work in the Virginias (207; pp. 48-51). The occurrence in the Keyser of the earliest known Appalachian species of several Devonian genera, of which *Rensselaeria, Beachia, Meristella,* and *Merista* are the most important,* was cited by the writer as evidence in favor of Devonian age. On the other hand, it was pointed out that comparison of Keyser faunas with underlying and higher beds is thrown out of balance by relative impoverishment of Upper Silurian assemblages in the Appalachian region. (See footnote on page 91.)

So far as correlation of the Keyser with specific horizons of the classical sections of Europe is concerned, the available data fail to provide a satisfactory answer. With continued growth of knowledge, increasingly critical comparisons of the faunas should lead to more confident views concerning age relationships (cf. Allan, 1). For the present, classification of the Keyser is considerably influenced by comparatively local considerations, and involves the question: Is the Keyser so intimately related to the Helderberg group that both must be placed in the same system?

Accepting the correlation of the Keyser with the Cobleskill to Manlius beds of central New York, as previously discussed, relationships that affect classification of the Keyser as Helderberg and Devonian versus pre-Helderberg and Silurian can be summed up as follows:

A. In favor of reference of the Keyser to the Helderberg group and the Devonian system:—

1. The Keyser represents an extensive invasion of marine waters into the Appalachian area, following prevalence of conditions less favorable for marine life. In a sense it inaugurated the important marine submergences that characterized the Lower Devonian as compared to the Upper Silurian of the Appalachian area.

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* See footnote, page 91.

2. The Keyser contains a considerable number of species that are very close to Coeymans and New Scotland forms, together with early species of several important Devonian genera. These are more abundant in the Keyser of the Maryland area, rare in its equivalents in New York. The age of the Keyser must eventually be determined, not on the basis of the comparatively impoverished faunas of the Cobleskill and Manlius of New York, but on the more complete and representative assemblages found in the Keyser farther south.

B. In favor of separation of the Keyser from the Helderberg group, and of its reference to the Silurian system:—

1. The Keyser is not equivalent in age to the beds included in the Helderberg group of the Helderberg Mountain area, since the term was revised in 1899. It is instead the correlate of beds below the Helderberg group as so defined (see Table XII).
2. The Keyser limestone is separated from the Coeymans limestone of the Helderberg group by a widespread disconformity.
3. The present weight of evidence favors the view that the Keyser is essentially equivalent to the Cobleskill-Manlius beds of central New York. The Silurian age of the latter beds has never directly been questioned. However, the importance of this argument is reduced by the imperfections of the faunas of the New York formations.
4. The Keyser fauna contains significant species derived from underlying Silurian beds. These include *Stenochisma lamellata, "Spirifer" vanuxemi,* and *Calymene camerata* from the Tonoloway, *Halysites catenulatus* from older formations.
5. The Keyser fauna contains only a few of the species which have been cited in support of the Devonian age of the Helderberg group.
6. The occurrence of linking species in both the Keyser and Helderberg faunas is not conclusive evidence of the Devonian age of both. They do show that the hiatus between the Keyser and Coeymans was not very long continued.

In view of the observations presented above, the writer believes it desirable to separate the Keyser limestone from the Helderberg group, and has tentatively referred the Keyser to the Silurian system. Apparent equivalence to the Cobleskill-Manlius of New York, long regarded as Silurian in American literature, favors this classification; though it is of doubtful value for comparison with European sections.

R. M. Allan (1) has recently suggested correlation of the Keyser with the generally non-marine upper Gedinnian of western Europe, on the basis of equivalence of the faunas of the Tonoloway and Helderberg with those of the lower Gedinnian and Siegenian, respectively. He also proposes to use the Maryland succession as a standard for the late Silurian and early Devonian, and to establish the base of the Devonian arbitrarily by incoming of the faunas associated with *"Spirifers"* of the *cyclopterus-hystericus* type—that is, at the base of the Coeymans in Maryland, and of the Siegenian in western Europe.

The evidence for correlation of the Tonoloway " *'Spirifer' vanuxemi* fauna" with the Gedinnian *"S." mercuri* fauna seems weak.* The Siegenian may include beds of Helderberg age; though Schuchert (179) regarded its fauna as related to that of the Oriskany, and it contains in the upper or "'*S.*' *hystericus* fauna" such post-Helderberg reminders as *Eodevonaria, Meganteris, Athyris, Tropidoleptus,* the multiplicate "*Spirifer*" *pellico,* and large-muscled *Stropheodonta gigas.* Asselberghs (A) and Maillieux (I) still regard the Gedinnian as basal Devonian. Further light is needed before the classification and, more fundamentally, the correlation of the Keyser with horizons of the classical European sections can be regarded as being firmly established.

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* For recent work and bibliographies see, for the Tonoloway, C. K. Swartz et al.; for the Gedinnian, Barrois et al., Asselberghs, Fuchs; for the Siegenian, Asselberghs and Leblanc, Dahmer, Maillieux, also Drevermann, and Scupin.

THE HELDERBERG GROUP

GENERAL RELATIONS

In the Helderberg Mountain area in New York, the Helderberg group includes the following formations, listed in stratigraphic order:

Alsen limestone, cherty; some upper beds questionably referred to Port Ewen limestone
Becraft limestone
New Scotland shale and limestone
Coeymans limestone

The Helderberg beds continue southward along the outcrop through Kingston (Van Ingen and Clarke, 215; pp. 1187-1197) and Trilobite Mountain, New York (Shimer, 192), to the Nearpass quarries, New Jersey (Weller, 223; pp. 81-96). In this distance, there is not much change in the Coeymans, New Scotland, and Becraft. The higher beds, however, undergo important modifications (see Table XIII). The Alsen limestone is questionably represented near Kingston, and is unknown farther south. Both the Alsen and part of the Becraft are probably displaced laterally by at least a portion of the Port Ewen formation, which is more argillaceous, and becomes 150 to 200 feet thick at Trilobite Mountain. At Trilobite Mountain and in New Jersey, two zones unknown farther north are intercalated between the Port Ewen formation and the "*Spirifer*" *murchisoni*—"*S.*" *arenosus* zone of the typical Oriskany. These are, respectively, the *Orbiculoidea jervensis* zone, above, and the *Dalmanites dentatus* zone, below. The *Orbiculoidea jervensis* fauna has uniformly been considered Oriskany in age. The *Dalmanites dentatus* zone was regarded as Helderbergian by both Clarke and Schuchert in earlier work (69). It was tentatively included in the Oriskany by Weller, though he pointed out its important affinities with Helderberg assemblages (223). Shimer (192) was more strongly convinced that the *D. dentatus* beds belong in the Oriskany group, and both the *D. dentatus* and Port Ewen beds were considered early Oriskany in age by J. M. Clarke in 1909 (64; pp. 129-134). The writer prefers to regard the Port Ewen and *D. dentatus* beds as part of the Helderberg group, because of their faunal relations with the "Becraft" limestone of Warren Point, Pennsylvania, and Monterey, Virginia.

The Helderberg formations of New Jersey extend into Monroe County in eastern Pennsylvania. The Coeymans and early part of the New Scotland are closely related in this area and in central and southern Pennsylvania. The relations of higher beds are less well marked, and are not so clearly understood at the present time. Cor-

TABLE XIII

Chart showing most plausible relationships, at present state of knowledge, of Helderberg and Oriskany beds in New Jersey, eastern and central Pennsylvania, and near Cumberland, Maryland. F. M. Swartz, Sept. 1938.

	CUMBERLAND, MARYLAND		LEWISTOWN, MIFFLIN COUNTY, PENNSYLVANIA		MANDATA AND DALMATIA, NORTHUMBERLAND COUNTY, PENNA.		MONROE COUNTY, PENNSYLVANIA		NEARPASS QUARRIES, NEW JERSEY		KINGSTON, NEW YORK	
Lower Devonian	Ridgeley ss. (type) "*Spirifer*" *arenosus*, "*S.*" *murchisoni* zone	Oriskany group	Ridgeley sandstone "*S.*" *arenosus*, "*S.*" *murchisoni* zone	Oriskany group	Oriskany sandstone and chert	Oriskany	Oriskany sandstone and shale "*S.*" *murchisoni* zone	Oriskany	"*Spirifer*" *murchisoni* zone	Glenerie ls. limestone Oriskany	Glenerie ls. "*S.*" *murchisoni* zone	Oriskany
	Shriver chert (type)		*O. jervensis-Metaplasia plicata* zone Shriver chert						*Orbiculoidea jervensis Metaplasta plicata* zone		Conelly congl.	
	T. multipunctata horizon not determined								*Dalmanites dentatus Rensselaeria mutabilis* zone	Port Jervis ls. (type)		
					(*T. multipunctata* fauna in Perry Co.)	Helderberg group	*T. multipunctata* Port Ewen shale	Helderberg group	Port Ewen shale	Helderberg group	Port Ewen shale (type) *Thlipsurella multipunctata* zone (Alsen ls.?)	Helderberg group
	Mandata shale	Helderberg group	Mandata shale ????	Helderberg group	Mandata shale and chert (type) ???		"*S.*" *concinnus* Becraft limestone		Becraft limestone "*S.*" *concinnus* zone		Becraft limestone "*Spirifer*" *concinnus* zone	
	New Scotland limestone *E. macropleurus* zone		New Scotland limestone *E. macropleurus* zone		*E. macropleurus* New Scotland limestone		New Scotland sh. and ls. *E. macropleurus* zone Kalkberg ls. memb.		New Scotland sh. and ls. *E. macropleurus* zone Kalkberg ls. member		New Scotland sh. and ls. *E. macropleurus* zone Kalkberg ls. member	
	Coeymans limestone *G. coeymanensis* zone		Coeymans limestone *G. coeymanensis* zone		(? present but covered?)		Stormville ss. memb. Coeymans limestone *G. coeymanensis* zone		Coeymans limestone *G. coeymanensis* zone		Coeymans limestone *Gypidula coeymanensis* zone	
							? ? ? ? ? ? ? ? ? ? ?		? ? ? ? ? ? ? ? ? ? ? ?		? ? ? ? ? ? ? ? ? ? ?	
Uppermost Silurian	Keyser limestone		Keyser limestone		Keyser limestone		Manlius limestone Rondout limestone Decker sandstone	Keyser	Manlius limestone Rondout limestone Decker limestone	Keyser	Manlius limestone Rondout limestone Cobleskill limestone Rosendale limestone Wilbur limestone	Keyser

knowledge, of Helderberg and Oriskany beds in New
he Maryland-Pennsylvania line.

INT, KLIN ANIA		MONTEREY TO CLIFTON FORGE, VIRGINIA		NEARPASS QUARRIES, NEW JERSEY		
tone one	Oris-kany	Ridgeley sandstone "*S.*" *arenosus* zone	Oris-kany	"*Spirifer*" *murchisoni* zone	Glenerie limestone	Oriskany
				Orbiculoidea jervensis Metaplasia plicata zone		
sa *nus* ime-	Helderberg group	*D. dentatus* *R. subglobosa* large "*S.*" *concinnus* Licking Creek limestone	Helderberg group	*Dalmanites dentatus Rensselaeria subglobosa* zone	Port Jervis ls.	
hale *les*		Mandata (?) chert *T. multipunctata*		Port Ewen shale (*Thlipsurella multipunctata* at Port Ewen) Becraft ls. "*Spirifer*" *concinnus* zone		Helderberg group
l *rus*		New Scotland limestone *E. macropleurus* zone		New Scotland sh. & ls. *Eospirifer macropleurus* zone Kalkberg ls. member		
sis	Coeymans	Coeymans limestone *G. coeymanensis* zone		Coeymans limestone *Gypidula coeymanensis* zone		
tone		Keyser limestone		Manlius limestone Rondout limestone Decker limestone		Keyser

relations which seem most plausible with existing knowledge are indicated in Tables XIII and XIV. To a considerable extent, however, these correlations must be considered tentative, and not fully established.

The features and relationships of the Helderberg deposits of Pennsylvania will be presented by discussion in turn of the characters and correlation of the Coeymans, New Scotland, Becraft, Port Ewen, Mandata, and Licking Creek formations.

THE COEYMANS LIMESTONE

General relations. Near the town of Coeymans, Albany County, New York, from which it receives its name, the Coeymans limestone is about 50 feet thick. It is very thick-bedded and finely to coarsely crystalline. It is underlain by the Manlius limestone, containing *"Spirifer" vanuxemi* and *Tentaculites gyracanthus.* It is overlain by the Kalkberg member of the New Scotland formation, in which the rich *Eospirifer macropleurus* fauna is introduced. Since 1899, the Coeymans limestone has been considered by New York geologists to be the base of the Helderberg group and of the Devonian system.

Distribution. The Coeymans formation is persistent in Pennsylvania along virtually all the outcrop belts shown in Figure 7. It has not, however, been observed in Schuylkill County, nor, by the writer, in the small anticlinal belts near Dalmatia in the southern part of Northumberland. It has not been seen in place in Perry County, but its fauna occurs with loose chert at the proper horizon at Clarks Mill.

As in the case of the other Helderberg beds and of the Keyser, its absence from Schuylkill County into Perry is believed to be due to an unconformity locally complicated by faulting.

Members and lithologic features. Throughout most of the areas where it crops out in Pennsylvania, the Coeymans maintains the lithologic features that characterize it in New York. That is to say, it is dominantly thick-bedded, gray, crystalline, and somewhat crinoidal. (See figures 8A, 9A, 17.) It also exhibits these characters in most of the areas where it is known in Maryland and the Virginias. The continuance of these lithologic characters over so large an area, and indeed the wide lateral persistence of so thin a formation, are remarkable facts.

In three more or less distinct areas in Pennsylvania, the Coeymans becomes very arenaceous, and grades in part into calcareous sandstones. These areas are (1) Monroe and Carbon County in eastern Pennsylvania; (2) Montour County; (3) the southwest tip of Franklin County. (See Figure 17.)

At the Nearpass quarries in New Jersey, the Coeymans contains no appreciable amount of sand. In eastern Monroe County, Pennsylvania, 8 to 10 feet of calcareous sandstone occur at the top of the Coeymans. I. C. White (228) named this sandstone the Stormville conglomerate, from exposures at that village about 3 miles southwest of Stroudsburg, where the sandstone is pebbly and 17½ feet thick, according to White's measurements. White also reported sand and some pebbles in parts of the 30 feet of limestone underlying the main body of pebbly sandstone at Stormville.

White applied the name Stormville not only to this sandstone, but also to underlying limestones and overlying shales of diverse ages. The name consequently must be modified or discarded. In the writer's opinion, the name will be useful and appropriate if restricted to the above described sandstone member of the Coeymans.

In view of the progressive increase in the Stormville member from New Jersey into Monroe County, and of a corresponding appearance of sand and pebbles in the Oriskany beds, White concluded that the sandstones continue to thicken and to displace intervening beds toward the southeast, and that they combine to form about 300 feet of ''Oriskany'' beds near Palmerton, in Carbon County. He was inclined to consider the base of the upper (=Palmerton) sandstone of this ''Oriskany'' as the equivalent of the Stormville sandstone horizon in Monroe County.

C. K. Swartz and the writer have recently shown (206) that this correlation is incorrect in important features. The relations of the sandstone beds seen in the Prince Company ore tunnel near Palmerton, and in surface exposures, to beds near Stroudsburg are illustrated in the following tabulation (See Figure 17):

	Prince Company ore tunnel, Carbon County, Pennsylvania	*Section on north side of Brodhead Creek, Monroe Co., Pennsylvania*
	Onondaga beds	Onondaga beds
White's "Oriskany" sandstone and shale of the Palmerton area	Palmerton sandstone, 145 feet Bowmanstown chert, 60 feet	Esopus shale
	Oriskany conglomerate and sandstone, 25 feet	Oriskany sandy limestone and shale, 115 feet
	New Scotland cherts, 40 feet	Port Ewen, Becraft (?), and New Scotland shale and some limestone, 225 feet
	Coeymans beds; Stormville sandstone and sandy residual clay, 50 (?) feet	Coeymans limestone, Stormville sandstone member at top, 80 feet
	Sandstone colored red and shale, probably upper Keyser, 30 feet Decker sandstone member of Keyser, 65 feet	Keyser limestone: Manlius and Rondout limestone and Decker sandstone members: 140 feet
	Bossardville limestone	Bossardville limestone

Fossils have not been found in the supposed Coeymans beds of the ore tunnel. They are referred to the Coeymans on the basis of their stratigraphic relations.

White (229) also reported Stormville sandstone at the old Grove Brothers quarry in Montour County, about 70 miles northwest of

Palmerton, and at Emerich and Lebo's quarry east of Dalmatia. The Coeymans age of the sandstone in Montour County was shown by Reeside (167), who found *Gypidula coeymanensis* in it. The supposed Stormville near Dalmatia needs confirmation; the Coeymans interval, not more than 6 feet thick, is concealed in the sections examined in that area by the writer.

Ten feet of sandstone occur at the base of the fine Helderberg section near Warren Point, Franklin County, which was first described by R. B. Rowe. The Coeymans age of this sandstone was first recognized by C. K. Swartz, who found *G. coeymanensis* in it in exposures along Elbow Ridge, south of the Warren Point section. The sandstone at Warren Point represents, in a general way at least, the same sandy phase which is seen in eastern Pennsylvania, and which accumulated along the southeastern margin of the old Coeymans seaway. Actual physical continuity of the sandstone from eastern Pennsylvania to Franklin County is perhaps not well established; it is clear, however, that the seaway extended from eastern New York across northeastern and central Pennsylvania into western Maryland, and there seems to be no reason to doubt that it had a continuous southeastern shore from eastern Pennsylvania to Maryland.

Boundaries. The Keyser-Coeymans contact has been discussed in the chapter describing the Keyser limestone. It is sharply marked and clearly disconformable, at least through central Pennsylvania.

In Monroe County, eastern Pennsylvania, the change from the calcareous Stormville sandstone member to the limestones at the base of the New Scotland is comparatively sharp. In Perry County, and the Dalmatia area of Northumberland County, the Coeymans beds have not been observed in place, at least by the writer, and the contact is therefore unknown.

The boundary between the Coeymans and New Scotland generally appears to be transitional, however. In central Pennsylvania its position is often somewhat questionable. The New Scotland beds are commonly more cherty and of finer texture than the Coeymans limestone, but the change is usually not abrupt. At Hollidaysburg, Painterville, and some other localities, shaly beds which occur above the thick-bedded Coeymans, do not contain *Gypidula coeymanensis,* and have been placed in the New Scotland. At Curtin there seems to be no lithologic boundary between the Coeymans and New Scotland beds. Near Warfordsburg, the thick-bedded, chert-poor limestones included in the Coeymans do not contain *G. coeymanensis* in the upper 3 or 4 feet. Instead *Meristella arcuata* is especially abundant, as it is in the next higher, chert-rich limestones included in the New Scotland. *Eospirifer macropleurus* appears a little above the base of the chert-rich beds, then becomes one of the commonest species. On a strictly faunal basis the top of the Coeymans could be placed at the top of the range of the gypidulas, several feet below the horizon where the cherts become dominant, and which is here used as the formational boundary.

Thickness. The Coeymans limestone thins from around 50 to 60 feet in the Helderberg Mountain area to 40 feet at the Nearpass quarries in New Jersey. It then increases in Monroe County, eastern Pennsylvania, to its maximum known thickness of nearly 80 feet. It thins to 50 or possibly 40 feet near Palmerton, Carbon County; then disappears, as has been pointed out, along the outcrop of its horizon across most of Schuylkill and through Lebanon and Dauphin counties into Perry County.

Throughout most of central and south-central Pennsylvania, it ranges from 3 to 10 feet thick. Toward the north, it increases to about 11 feet near Jersey Shore in Lycoming County. It reaches its maximum known thickness for central and south-central Pennsylvania near Warfordsburg, Fulton County, where it measures 20 to 24 feet.

South of Pennsylvania, the Coeymans is 50 to 55 feet thick near Monterey, Virginia, then disappears by unconformity in the southwestern part of that State.

Economic value. The Coeymans limestone is generally satisfactory for agricultural lime and road metal (147, 148), and at places could be used for building stone. Where it is only a few feet thick, it can not be worked as a rule except with the underlying limestones. In Monroe County, where it is thickest, it is distinctly arenaceous.

Fauna. The Coeymans limestone and sandstone members are persistently characterized by *Gypidula coeymanensis.* The limestone beds contain layers that are largely composed of the valves of this species. *G. coeymanensis* has been observed at virtually all exposures of the Coeymans. Good specimens can be distinguished from the middle Keyser *G. prognostica* by the higher, narrower and more numerous plications.

Species commonly present in association with *G. coeymanensis* include: *Favosites helderbergiae, Rhipidomella oblata, Leptaena rhomboidalis, Stropheodonta varistriata, Strophonella punctulifera, Atrypa reticularis.* Less frequent are: *Leptostrophia planulata, Strophonella leavenworthana, Schuchertella woolworthana, "Spirifer" cyclopterus, Phacops logani, Dalmanites micrurus. Meristella arcuata* is profuse at the top of the beds included in the Coeymans near Warfordsburg, though above the range of *G. coeymanensis. Isorthis perelegans* occurs in a similar position at Warren Point. It has been reported with *G. coeymanensis* at some localities; but unquestioned specimens have not been observed with the latter species by the writer.

Correlation with New York, Maryland, and the Virginias. By virtue of its lithology, stratigraphic position, and especially of its fauna, the Coeymans limestone of Pennsylvania is clearly equivalent, within narrow limits, to the Coeymans of New Jersey and eastern New York, to the northeast; and to that of western Maryland and the Appalachian Ridge and Valley region of the Virginias, to the southwest. It is continuous along the outcrop from eastern Pennsylvania into the first of these areas; from central Pennsylvania into the second. Furthermore, there is every reason to believe that the Coeymans extends from central Pennsylvania into the New York area, below the cover of Devono-Carboniferous rocks seen at the surface in northeastern Pennsylvania and south-central New York. It seems equally clear that these areas were parts of a continuous basin of marine sedimentation during Coeymans time.

Correlation with Gaspé and western Tennessee. It is highly probable that the Coeymans sea of the middle Appalachian region also extended northward to the Gulf of Saint Lawrence, and southwestward to western Tennessee. According to Clarke (64), the fauna of the Saint Albans beds of the Gaspé region contains numerous Helderbergian species, including "*Sieberella galeata,*" identified by Clarke with the Coeymans species which was later named *Gypidula coeymanensis* by Schuchert. The Olive Hill formation of western Tennessee contains a very characteristic Coeymans fauna, according to Dunbar (83).

The Saint Albans contains such species as *Levenea subcarinata. Leptostrophia beckii, "Spirifer" perlamellosus,* and *Atrypina imbricata,* which are more suggestive of the New Scotland than of the Coeymans. *Eospirifer macropleurus* was not observed by Clarke. The ranges of the species in the Saint Albans were not determined. The formation may well represent parts of both the Coeymans and New Scotland farther south.

It is probable that the Coeymans seas had some oceanic connection leading southward through the area of deposition of the Olive Hill in Tennessee. The increased circulation resulting from opening of the Coeymans seas both to the north and south may have been a factor that helped to produce the relative uniformity of the Coeymans sediments and faunas in the middle Appalachian area; probably combined with low altitude of the adjacent land, so that little alluvial material was carried into the trough.

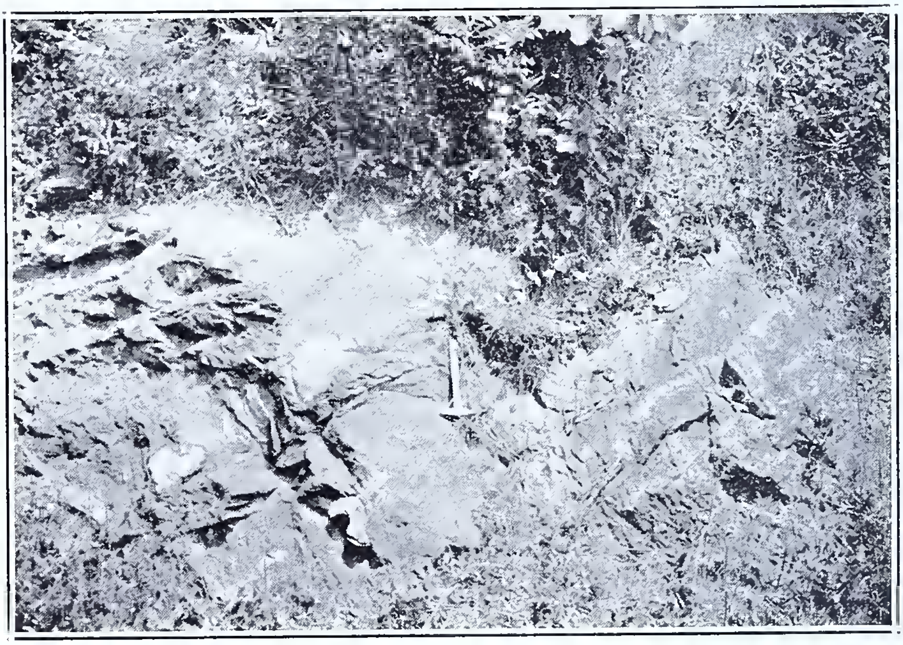
THE NEW SCOTLAND FORMATION

General relations.—The type New Scotland of eastern New York consists of calcareous shale and impure limestone and some chert, above, and cherty limestone, at the base. The cherty limestone was named Kalkberg limestone by Chadwick in 1908 (43), and was considered by him a distinct formation. More recently Goldring (105) has considered it a member of the New Scotland. The New Scotland lies between purer Coeymans limestone below, and Becraft limestone above. It contains a large fauna, characterized especially by *Eospirifer macropleurus.* Both *E. macropleurus* and *Gypidula coeymanensis* have been reported from the Kalkberg member.

Distribution.—Beds of New Scotland age are believed to extend along all the outcrop belts shown in Figure 7; except that they have not been observed near the end of the line entering Schuylkill County from the east.

Members and lithologic features.—In parts of Monroe County, eastern Pennsylvania, the New Scotland is similar to that of eastern New York. It is largely composed of somewhat calcareous, fossiliferous shale. At the base is impure siliceous and argillaceous limestone, which contains a good deal of interbedded dark chert and corresponds in position to the Kalkberg member in the Hudson River valley. As seen on Brodhead Creek, these Kalkberg beds are very suggestive of parts of the Port Ewen near Kingston, New York. They contain nodular masses of purer limestone, weathering gray, embedded in a more impure limestone, which weathers brown (see Figure 11).

In the ''white clay'' quarries near Kunkletown (Figure 13), and in the Prince Company ore tunnel near Palmerton, the New Scotland is seen as more or less solid, bedded chert, which is weathered white, together with residual fine grained, siliceous, clayey material. These cherts have been found at Andreas, near the Schuylkill-Carbon County line, by C. K. Swartz; but have not been observed in Schuylkill County west of this point.



Photograph by A. B. Cleaves

Figure 11. **Cherty limestone or Kalkberg member, lower part of New Scotland, showing large nodules of limestone, weathering gray, embedded in more impure limestone, weathering brown. The chert layers and nodules are dark and inconspicuous. Section on north side of Brodhead Creek, near Minisink Mills, Monroe County (See also Figure 26).**

In central Pennsylvania, cherty limestone beds containing *Eospirifer macropleurus* form a distinct lithologic unit and are very persistent. For reasons which are discussed later in this paper, the name New Scotland is provisionally used in central Pennsylvania only for these cherty limestones and a sandstone equivalent. *Eospirifer macropleurus* also occurs, however, in some areas in the lower part of the next overlying Mandata shale and chert. (See Figure 17.)

As used in this sense, the New Scotland of central Pennsylvania consists of finely crystalline gray limestone and interbedded chert, commonly in layers 2 to 4 or 6 inches thick. These cherts are gray to black when fresh, but tend to weather white while still quite solid. At Hollidaysburg and near Bedford, on the west, 1 foot of calcareous shale occurs at the base of the cherty limestone. At Painterville and Lewistown, in Mifflin County, the solid cherty limestone is underlain by about 4 feet of shaly limestone, with 6-inch nodules of purer limestone. This impure limestone is included in the New Scotland, but may prove to belong in the Coeymans.

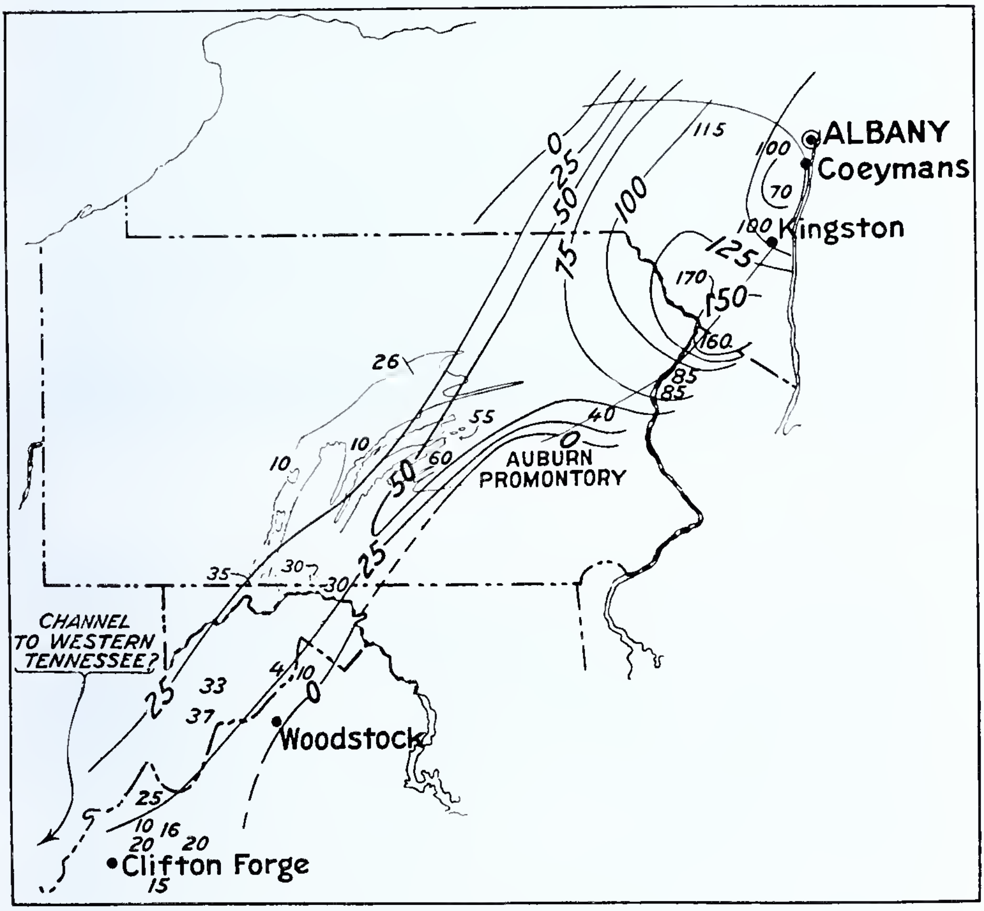


Figure 12. **Sketch map illustrating known variations in thickness of *Eospirifer macropleurus* beds in New York, Pennsylvania, Maryland, and parts of the Virginias. In New York, New Jersey and Monroe County these beds include the New Scotland shaly limestone and cherty Kalkberg member; in central Pennsylvania the New Scotland limestone plus the *E. macropleurus*-bearing beds of the Mandata shale and chert; in the Virginias the New Scotland limestone and Healing Spring sandstone member. Isopachous interval twenty-five feet.**

At Clarks Mill and Falling Springs, Perry County, the cherty limestone is displaced by medium-bedded solid calcareous sandstone. This sandstone is best seen at the second locality, and is consequently here named Falling Springs sandstone member of the New Scotland.

Boundaries. The contact of the New Scotland with the underlying Stormville sandstone of the Coeymans of eastern Monroe County is well defined, as has been described. The contact with the Coeymans of central Pennsylvania generally appears to be transitional, and its exact position is sometimes questionable.

The beds here described under the name New Scotland are overlain in eastern Monroe County by Becraft limestone; in Carbon County by sandstone of probable Oriskany age; in central Pennsylvania by Mandata shale and chert. The upper contact in Monroe and Carbon counties is not well exposed nor fully understood. In central Pennsylvania, the change from New Scotland limestone to Mandata shale and chert can usually be located within a few inches, but exhibits no evidence of unconformity.

Thickness. The New Scotland shale and limestone is 160 feet thick at the Nearpass quarries, New Jersey, according to the measurements of Weller. It includes at the base 20 feet of cherty limestone, referable to the Kalkberg member. It thins to 80 feet in eastern Monroe County, including 25 to 30 feet of Kalkberg beds. The New Scotland cherts are only 40 feet thick in the ore tunnel near Palmerton. In the writer's opinion they disappear by disconformity in the Auburn region in Schuylkill County.

Throughout central Pennsylvania, the cherty New Scotland limestone varies from about 10 to 30 feet where it has been studied and exposures are satisfactory.

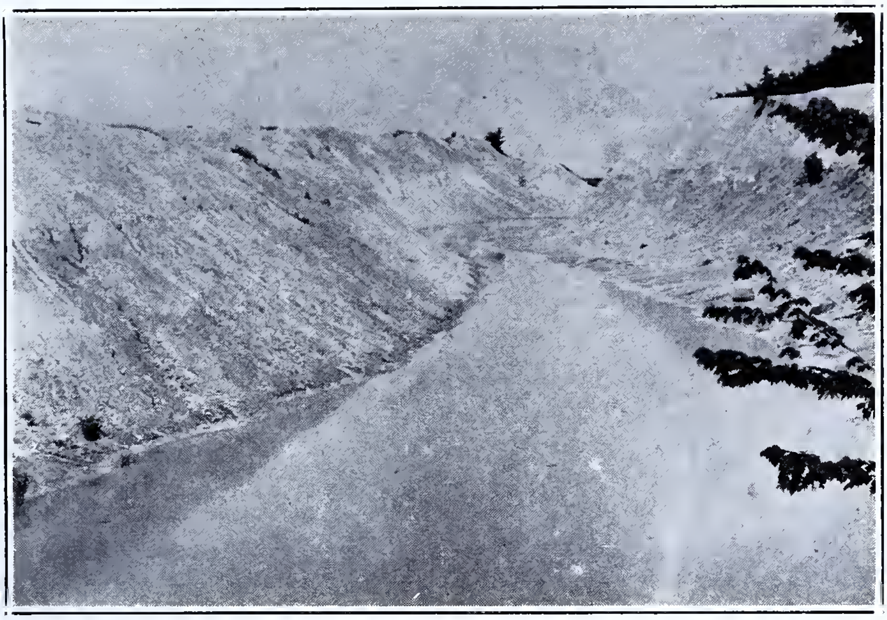
As has been pointed out, part of the Mandata shale and chert contains a typical New Scotland *Eospirifer macropleurus* fauna. For the purpose of illustrating the variations in thickness of beds of New Scotland age, the *E. macropleurus* bearing strata of the Mandata have been included with the New Scotland limestones of central Pennsylvania, in the accompanying isopachous map (Figure 12).

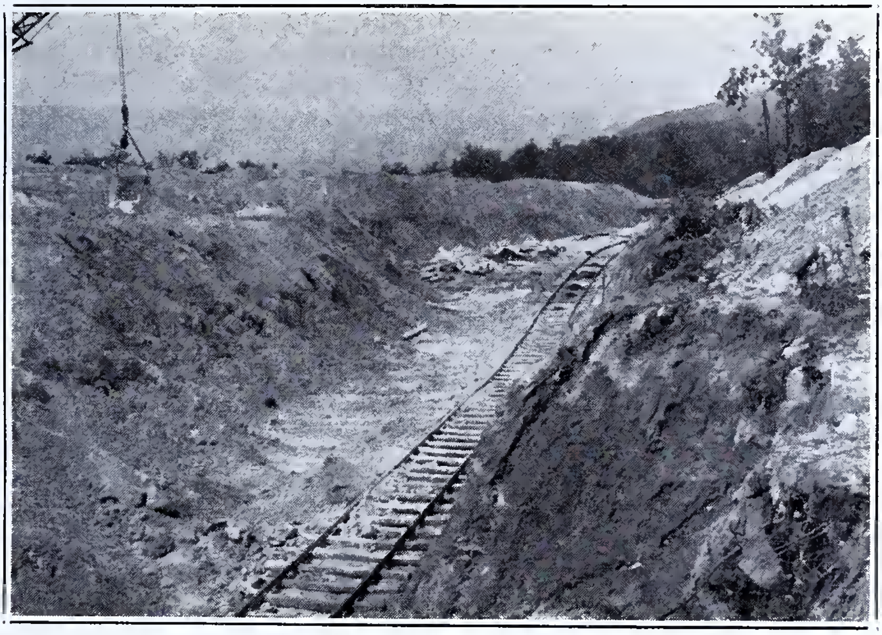
The writer hopes it will be realized that the data used for this and other accompanying isopachous maps are not yet sufficient to provide a detailed picture of the thicknesses of the formations. The maps are intended to present only a very general picture of the main axes and basins of deposition. Furthermore, they represent the amount of deposition, not necessarily the relative depth of water. In general the thickest deposits will tend to lie along the main channels of submergence, since these beds do not seem to include important deltaic deposits, and the basins were comparatively narrow. Nevertheless, the rate of deposition may have varied considerably from one place to another.

Economic value. The New Scotland cherts are deeply weathered where exposed along Chestnut Ridge, near Kunkletown, Monroe County. The residual white clay is being quarried extensively by the Universal Atlas Cement Company (134). Similar white clays near Saylorsburg are believed to have been formed from the younger Bowmanstown chert.

In central Pennsylvania, the cherty New Scotland limestone is too siliceous to be of value for agricultural lime. It is, however, quarried at some places along with underlying beds.

Fauna. Eospirifer macropleurus is persistent throughout the New Scotland beds (see plates of fossils). In eastern Pennsylvania, it is common in the lower Kalkberg limestone member, and somewhat more





Photographs by A. B. Cleaves

Figure 13. Views of white clay quarries of Universal Atlas Cement Company, one-half mile south and four miles east of Kunkletown, Monroe County, Pennsylvania. The clay is residual from weathering of cherty beds of the New Scotland and possibly of the Port Ewen.

abundant in the overlying calcareous shales; at least where these are seen in fine exposures along the bank of the Delaware River at Wallpack Bend. It has been found by C. K. Swartz in the New Scotland cherts at Andreas, in Schuylkill County near the Carbon County line. It is more or less abundant through the cherty New Scotland limestone in central Pennsylvania, but frequently makes its first appearance several feet above the base of these beds. It occurs in at least the upper part of the Falling Springs sandstone member in Perry County.

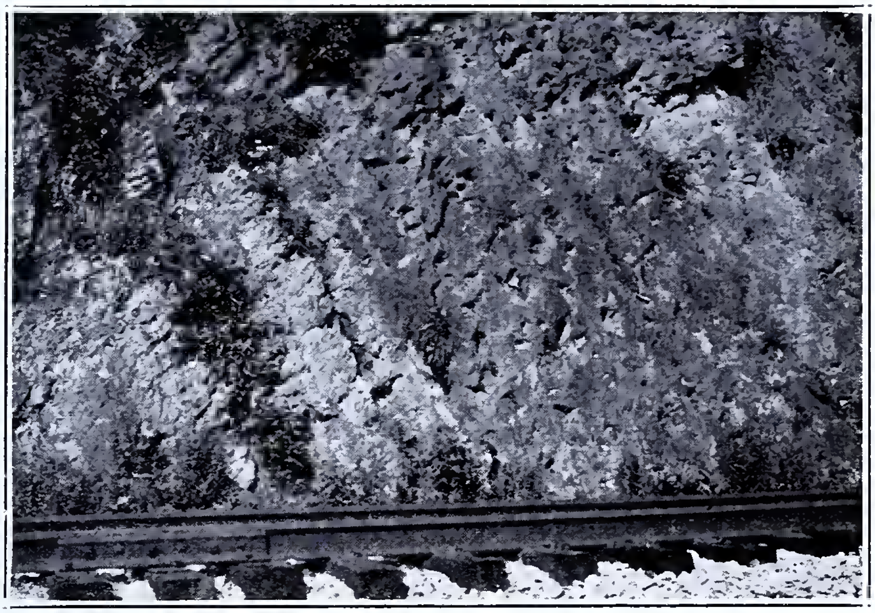
Other common species include *Rhipidomella oblata, Isorthis perelegans, Leptaena rhomboidalis, Leptostrophia planulata, L. beckii, Strophonella punctulifera, Schuchertella woolworthana, Eatonia medialis, "Spirifer" cyclopterus, "S." perlamellosus, Meristella arcuata, Anoplotheca concava, Phacops logani.* Also present are unidentified bryozoa, *Levenea subcarinata, Strophonella leavenworthana, Chonostrophia helderbergiae, Uncinulus abruptus, Trematospira multistriata.*

Correlation with New Jersey and New York. Because of its lithologic characters, including division into calcareous shale, above, and cherty limestone below; its relations to the adjacent Coeymans and Becraft limestones; and especially because of the occurrence of *Eospirifer macropleurus* in abundance, together with numerous other Helderbergian species, the New Scotland of eastern Monroe County is clearly the southerly extension of the New Scotland of New Jersey and eastern New York. *E. macropleurus,* it is true, is reported to occur rarely in the post-Becraft Alsen limestone and Port Ewen beds of the Hudson River valley. Nevertheless, the abundance of this species in the New Scotland appears to be significant.

The lower cherty limestone or Kalkberg member in eastern Monroe contains no *Gypidula coeymanensis,* so far as known. Its base is probably younger than the base of the Kalkberg member at the type area near Catskill, New York. *G. coeymanensis* is not known in the similar cherty limestones in New Jersey and at Trilobite Mountain, New York. *Bilobites varicus* occurs in the cherty limestone at the latter localities, and is abundant in the Kalkberg at Catskill; but it was not observed in the Kalkberg beds in Monroe County.

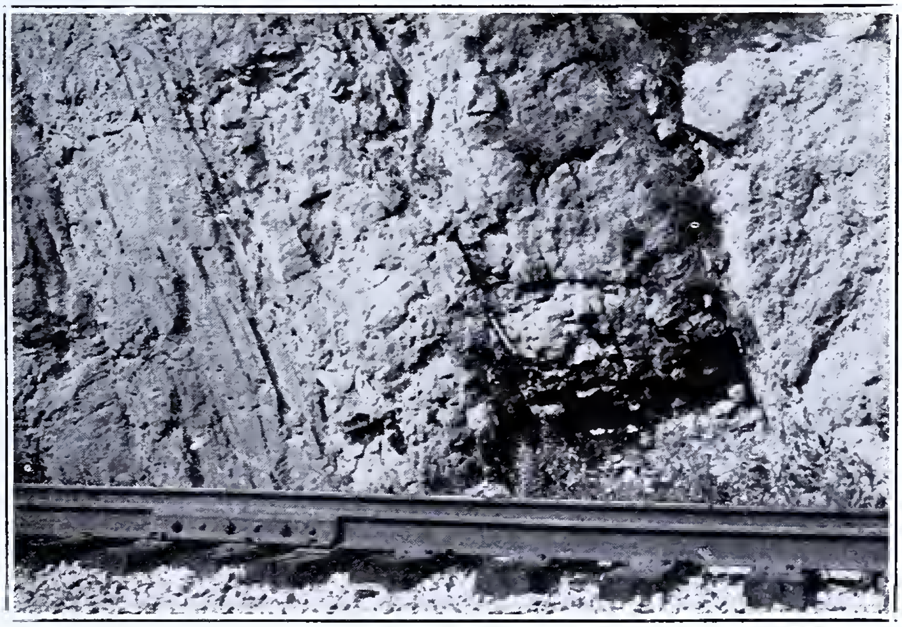
The cherty New Scotland limestone of central Pennsylvania corresponds more closely in lithology to the Kalkberg beds in eastern New York, than to the main body of the New Scotland of that area. Furthermore, at Mandata, southern Northumberland County, the lower half of the overlying Mandata shale and chert contains a typical *Eospirifer macropleurus* fauna. In the future it may prove possible to separate the *E. macropleurus* beds of the Mandata, and include them in the New Scotland, to which they clearly correspond in age. The underlying cherty limestone could then be referred to the Kalkberg member, at least near Mandata.

In west and south-central Pennsylvania, *E. macropleurus* is persistent and abundant in the cherty New Scotland limestone, and is unknown in the overlying shale beds. The top of the cherty limestone may be younger here than at Mandata, and may correspond more closely in age to the top of the New Scotland in New York.



Photograph by A. B. Cleaves

Figure 14. *A.* **Upper part of Port Ewen formation, showing hollows left by solution of nodules of purer limestone. West Shore Railroad, about 1,500 feet south of Wilbur Bridge, south of Kingston, New York.**



Photograph by A. B. Cleaves

B. **Contact between Oriskany (Connelly) conglomerate, to right of hammer, Port Ewen beds to left. West Shore Railroad about 1,500 feet south of Wilbur Bridge, New York.**

Correlation with Maryland and the Virginias. The cherty New Scotland limestone of south-central Pennsylvania continues southward through Maryland into the Virginias. In these areas *Eospirifer macropleurus* is also persistent, and is not known in the next overlying beds.

Correlation with other areas. The Saint Albans beds of the Gaspé region, eastern Quebec, contain many New Scotland species. They may in part correspond to the New Scotland of the middle Appalachian region; but doubt is thrown on this correlation by the absence of *Eospirifer macropleurus.*

Distinctive New Scotland faunas have been reported by Dunbar (83) from the Birdsong shale of western Tennessee, and by Reed from the Haragan marl of Oklahoma. It is reasonably clear that the New Scotland seaway reached southward from eastern New York, through central Pennsylvania, western Maryland, and the Monterey area in west-central Virginia, to western Tennessee. It probably then continued southward to form an oceanic connection.

THE BECRAFT LIMESTONE AND PORT EWEN SHALE OF MONROE COUNTY

General relations. At Becraft Mountain, opposite Catskill, New York, the New Scotland beds are overlain by Becraft limestone, 45 feet thick, and consisting of light gray, crystalline, in part crinoidal beds. Above the Becraft are 25 feet of impure cherty Alsen limestone, capped by Oriskany beds.

The Becraft continues southward to Kingston, where it is 35 feet thick, and into New Jersey, where it is 15 to 20 feet thick. The Alsen beds disappear southward, being displaced by Port Ewen beds which become about 150 feet thick in the type section along the West Shore Railroad near Kingston (see Figure 14A, B), and about 200 feet near the New York-New Jersey boundary. To what extent the Port Ewen is younger than the Alsen is unknown; the basal part of the Port Ewen near Kingston is regarded by some authors as Alsen.

Distribution. In Pennsylvania, Becraft limestone and Port Ewen shale occur as units to which these names can be applied only in the eastern part of Monroe County. The Mandata shale and Licking Creek limestone of central and south-central Pennsylvania are partially of these ages, as will be brought out in subsequent discussion.

Lithologic character and thickness. On the Walpack bend of the Delaware River, at the eastern tip of Monroe County, the New Scotland shales are overlain by 20 feet of thick-bedded, finely crystalline blue limestone, here regarded as the Becraft. At Brodhead Creek, 10 miles farther southwest, 14 feet of impure limestone, occurring near the same position, are more questionably referred to the Becraft.

Ash-gray shale, evidently Port Ewen in age, occurs above the Becraft limestone at Walpack Bend and Brodhead Creek (see Figures 17, 26). It is about 150 feet thick at the first locality, where the position of its top is uncertain; about 135 feet thick at the second place. The shale breaks obliquely across the bedding, so that it is difficult to obtain strikes and dips.

The Becraft and Port Ewen beds disappear along the line of outcrop to the southwest, at least in the form seen in eastern Monroe County. They may be represented in some small part in the upper portion of the 40 feet of chert, here classed as New Scotland, in the sections near Kunkletown and Palmerton. (See Figure 17.)

From recent studies it is clear that beds of Port Ewen, and less certainly of Becraft age continue westward from their outcrop in New York; extending beneath the younger sediments of northeastern Pennsylvania and into central Pennsylvania, where they are represented by part of the Mandata shale and chert. The Licking Creek limestone, of late Helderberg age, appears near Warren Point along

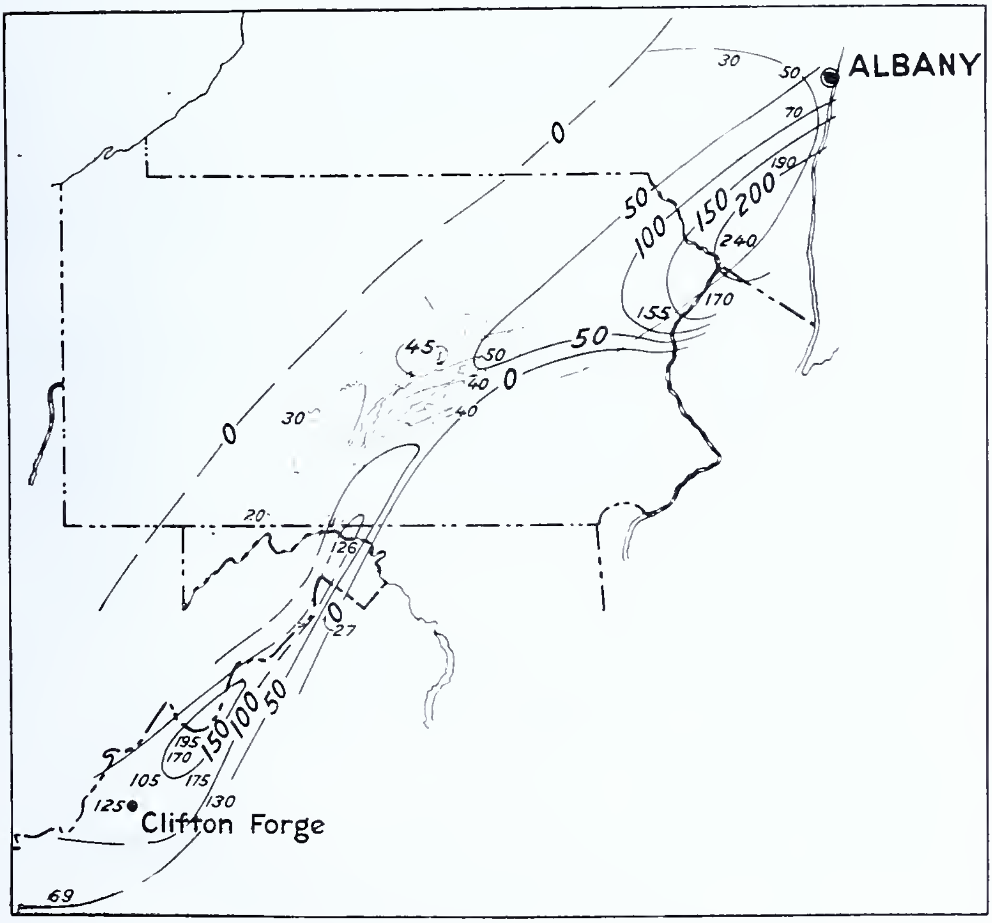


Figure 15. **Sketch map illustrating known variations in thickness in Pennsylvania and New York of Helderberg beds above the New Scotland *Eospirifer macropleurus* beds. Toward the northeast, these beds include the Becraft, Alsen, and Port Ewen, plus the *Dalmanites dentatus* beds, about thirty feet thick, in New Jersey. In central Pennsylvania, the beds are represented by parts of the Mandata shale and chert, the *Eospirifer macropleurus* beds of this formation being omitted; from Warren Point, near the Maryland line, south to Clifton Forge area of Virginia, the thicknesses are based on Mandata (?) shale and chert, and the Licking Creek limestone. Isopachous interval fifty feet.**

the Maryland line, then continues southward into Virginia. The known variations in thickness of these combined, post-New Scotland Helderberg deposits, are illustrated in a general way in Figure 15.

The Becraft-Port Ewen beds reach their greatest thickness at Trilobite Mountain, near the New York-New Jersey boundary, where they total about 215 feet, according to Shimer. If the *Dalmanites dentatus* beds are added, the thickness at Trilobite Mountain is 245 feet; if they are omitted, there is little shift in the isopachs.

The late Helderberg beds thin rapidly toward central Pennsylvania, where they are represented by parts of the Mandata shale and chert. They thicken again near Warren Point, on the Maryland line, and in the vicinity of Monterey, Virginia, where they include Mandata (?) shale and chert and Licking Creek ("Becraft") limestone. Doubt is thrown on some of the thicknesses indicated in western Maryland and West Virginia, because of questions concerning the relations of Mandata and Shriver beds in parts of those areas. Definite thinning and disappearance of these beds on the eastern side of the trough as shown in northern Virginia, is indicated by work near Winchester and Woodstock by C. K. Swartz and the writer.

Boundaries. The contacts of the Becraft are not exposed at either the Wallpack Bend or at Brodhead Creek. The Port Ewen may be overlain at Wallpack Bend by beds containing the *Dalmanites dentatus* fauna seen in New Jersey; unfortunately the top of the Port Ewen and the next overlying beds have not been seen at this locality by the writer. At Brodhead Creek, the top contact of the Port Ewen is well exposed and is sharply defined, at least as here drawn. The next overlying beds are ash-gray shales, a little more resistant and probably a little more siliceous than the Port Ewen. Fossils are rare, and unquestioned Oriskany fossils have not been observed for some distance above the contact. There is no sign at this locality of the *Dalmanites dentatus* fauna, which occurs in the beds next above the Port Ewen in New Jersey; nor of the next higher *Orbiculoidea jervensis* fauna, also seen in New Jersey. These two zones may be absent by disconformity at the Brodhead Creek section.

Economic value. The Becraft limestone of eastern Monroe County is too thin and impure for quarrying. The Port Ewen beds have no known economic value.

Fauna. The Becraft limestone at Wallpack Bend contains *Levenea subcarinata* and *"Spirifer" cyclopterus* (see plates). The more characteristic *"Spirifer" concinnus* and *Gypidula pseudogaleata* were not observed. Faunas were not obtained from the still more questionable Becraft at Brodhead Creek.

On Brodhead Creek, at least two rather distinct faunas are represented in the Port Ewen beds. Near the middle are *Platyorthis planoconvexa* (a), *Leptostrophia oriskania* (a), *"Spirifer" concinnus* (c), but in part with faintly grooved ribs and thus possibly *"S." aroostookensis.* Also present is *Chonetes* n. sp., with divergent, pustulose ridges on the interior of the ventral valve.

In the upper foot are lenses of highly fossiliferous limestone. The fauna includes: *Rhipidomella musculosa* (rr), *Chonetes* n. sp. (same as above) (a), *C. aroostookensis* (a), *"Spirifer" concinnus* var. (c), *"S." murchisoni* (r), *Dalmanites* sp. (not *D. dentatus*) (a), *Homalonotus vanuxemi* (c), numerous ostracoda, including *Thlipsurella multipunctata.*

Correlation with New Jersey and New York. The limestone beds above the New Scotland at Wallpack Bend are considered Becraft because their lithology is reasonably close to that of the Becraft of New Jersey, and because of their position between the New Scotland and Port Ewen. No other solid limestone of this type is known to occur near this horizon in this general area. The observed fauna is not, however, distinctively Becraft. Age of the beds tentatively included in the Becraft at Brodhead Creek is still less certain.

The next overlying shales are correlated with the Port Ewen of New Jersey and New York because of comparable lithology, similar stratigraphic position, and some features of the fauna. The writer in 1937 collected the following species in the Port Ewen in the type section along the West Shore Railroad south of Kingston: *Leptostrophia oriskania* (c), *Chonetes* n. sp., same as at Brodhead Creek (r), *Thlipsurella multipunctata* (c). *Platyorthis planoconvexa. "Spirifer" concinnus,* and *"S." murchisoni* have also been reported from the Port Ewen in the type area.

On the other hand, *Chonetes aroostookensis* and *"Spirifer" aroostookensis* are species never before recognized in the Port Ewen. Both occur in the Chapman sandstone of Maine, and the *"Spirifer"* is abundant in the Oriskany (?) beds at Highland Mills, New York (Clarke, 64). The importance of the shallow grooves seen along some of the ribs of *"S." aroostookensis* (?) needs further study. These are very faint in the material from Brodhead Creek, and are seen only with exceptional preservation. They should be looked for in material from the Port Ewen of New York. They tend to be lost with slight exfoliation of the shell material.

Correlation with other areas. The Port Ewen and to some extent the Becraft of New York are represented by faunas occurring in the Mandata and Licking Creek beds of central and south-central Pennsylvania. Their relationships will be considered in the discussions concerning those formations.

The Dalhousie beds of New Brunswick contain typical *"Spirifer" concinnus,* along with *"S." perlamellosus* and other Helderbergian species. These beds are probably equivalent to the Becraft, at least in part.

THE MANDATA SHALE AND CHERT

General relations. The name Mandata is here proposed for shale and chert beds, which occur above the cherty New Scotland limestone through central Pennsylvania, and which are about 90 feet thick at the section one-quarter mile south of Mandata (Bull Run of Millersburg topographic sheet), near the southern border of Northumberland County, Pennsylvania. In part these beds are New Scotland in age, in part they are younger. (See Tables XIII and XIV.) In part they contain so few fossils that correlation is uncertain. They seem, however, to form a continuous body of rock. (See Figure 17.)

Distribution. The beds here included in the Mandata are believed to occur in central Pennsylvania throughout the belts of outcrop shown in Figure 7; though they have not been definitely identified as yet in Lycoming, Clinton, and Centre Counties.

Lithologic features. In the type section near Mandata, the Mandata beds consist of the following lithologic divisions, arranged in stratigraphic order:

	Feet
Oriskany chert and sandstone	
Mandata shale and chert	
Thin-bedded shale, no fossils observed.	24
Medium-bedded impure dark chert, and interbedded dark gray shale. A 6- to 9-inch bed of impure limestone at 7 feet. Late New Scotland fauna, but *Eospirifer macropleurus* not observed.	20
Thin-bedded dark gray shale, and a few interbedded layers of impure chert. *E. macropleurus* (c).	14½
Thin-bedded gray shale, and four interbedded layers of finely crystalline limestone. *E. macropleurus* (c).	8½
Thin-bedded shale; a 4-inch bed of impure limestone at 5 feet. *E. macropleurus* (c).	20
Concealed.	4
New Scotland limestone.	

At Selinsgrove Junction, 10 miles north of Mandata, the Mandata beds consist of 55 feet of dark gray shale with little if any chert and very few fossils. This relatively barren and chert-free phase extends to the west and southwest, where it thins still further.

At Clarks Mill in Perry County, 25 miles southwest of Mandata, the Mandata beds are about 80 feet thick. They are not well exposed. Relatively solid chert is, however, fairly abundant in the lower half or so; while the upper beds weather to punky, siliceous fragments, representing impure chert or siliceous shale. The Mandata beds of Perry County were termed the "yellow flint shale" by Claypole (72) (see Table VIII).

Near Warfordsburg, Fulton County, similar siliceous shale and impure cherts occur between the New Scotland limestone and Ridgeley sandstone. In the section along the Western Maryland Railroad, near Tonoloway, Maryland, about 10 miles southwest of Warfordsburg, they were referred to the Lower Oriskany (= Shriver chert) by Ulrich in 1912 (214). They lack the *Eospirifer macropleurus* fauna of the lower part of the Mandata at Mandata and in Perry County, but they do not contain the faunas characteristic of the Shriver in central Pennsylvania (see the writer's descriptions of the Hollidaysburg and Lewistown sections, 208). They contain some, at least, of the fossils of shaly beds that lie between the New Scotland and Licking Creek ("Becraft") limestones at Warren Point, 7 miles east of Warfordsburg. The relations of these beds in the Warfordsburg area are not wholly clear as yet; but they are tentatively referred to the Mandata shale and chert pending further investigation.

Boundaries. At Mandata, the Mandata beds lie between the cherty New Scotland limestone below, and solid, relatively pure dark cherts, which weather whitish, above. Sandy beds at the top of these overlying cherts in nearby sections at Dalmatia contain a *"Spirifer"* *murchisoni* fauna, so that they are evidently Oriskany in age. The contacts of the Mandata with the adjacent beds are not well exposed, but appear to be rather sharp.

At Selinsgrove Junction, to the north, the Mandata beds occur between the same formations that bound them at Mandata. The contacts are well exposed, and both are fairly well defined. The contacts are also well marked in Perry County, where the Mandata rests on the Falling Springs sandstone member of the New Scotland, and is again overlain by the more solid Oriskany chert beds.

In more westerly sections, as near Lewistown, Mifflin County, Hollidaysburg, Blair County, and the Devils Backbone, near Cumberland, Maryland, the Mandata shale lies above the cherty New Scotland limestone and below the Shriver chert, considered part of the Oriskany group. The change from New Scotland limestone to Mandata shale occurs within a few inches. The contact with the Shriver is abrupt at Hollidaysburg and the Devils Backbone. At Lewistown, the change in lithology is less well defined, and the exact position of the Mandata-Shriver contact is somewhat questionable.

In the vicinity of Warfordsburg, Fulton County, the beds tentatively referred to the Mandata lie between cherty New Scotland limestone below, and Ridgeley sandstone above. The contacts have not been seen. At Warren Point, shaly limestones or calcareous shales resting on the cherty New Scotland limestone, are included tentatively in the Mandata. They are apparently transitional with the New Scotland, and they are overlain by a 35-foot concealed interval, evidently formed of rather weak rocks as they are eroded back and form a bench along the bluff. These may also be Mandata. The concealed interval is overlain by Licking Creek ("Becraft") limestone.

Thickness. Through the outcrop area of the Helderberg beds in central Pennsylvania, the deposits here included in the Mandata shale and chert exhibit a rather definite pattern of variation in thickness, at least within the limits of present knowledge. There is an axis of maximum deposition running northeast-southwest through Mandata and Dalmatia in southern Northumberland County, and Clarks Mill in the central part of Perry. This axis apparently continues northeastward through Grovania, where the "Stormville" of I. C. White (228) is very likely equivalent to the Mandata of this discussion. Thicknesses are 90 feet at Mandata, about 90 at Clarks Mill. The presumably equivalent shales at Grovania are about 100 feet thick according to both White (229) and Reeside (167). Along the southwestern continuation of this axis, the beds tentatively included in the Mandata near Warfordsburg are about 80 feet thick.

The formation thins to the west. Thus it is 40 feet thick at Lewistown in Mifflin County, 30 feet thick at Hollidaysburg in Blair County, 20 feet thick at the Devils Backbone, near Cumberland, Maryland. Part or all of this westward thinning may involve the lateral change of the lower part of the Mandata at Mandata into the beds here included in the New Scotland cherty limestone; but there is no marked concommitant thickening of these cherty limestone beds. In the accompanying isopach maps the *Eospirifer macropleurus* beds of the Mandata shale are included with the New Scotland in Figure 12 and are omitted from the post-New Scotland beds in Figure 15.

Fauna. At Mandata, Northumberland County, the lower 45 feet of the Mandata formation contains a large and very characteristic New Scotland fauna. (See plates of fossils.) This includes *Levenea subcarinata, Leptaenisca concava, Leptostrophia beckii, Atrypina imbricata, Eatonia singularis, Eospirifer macropleurus, "Spirifer" cyclopterus, "S." perlamellosus, Anoplotheca concava, Trematospira equistriata.* This fauna is, if anything, more distinctively New Scotland than that of the underlying limestones to which the name New Scotland is applied.

The next overlying 20 feet of chert and limestone contains virtually the fauna above listed, except that *Eospirifer macropleurus* was not observed. No fossils were found in the upper 25 feet of the formation.

In Perry County, the beds are less well exposed. Nevertheless, the collections obtained show that *E. macropleurus* is again common through the lower half of the formation, and apparently absent in the upper half. The upper beds, furthermore, contain an ostracode fauna characterized by *Thlipsurella multipunctata* and other ostracoda of the Port Ewen of Monroe County, Pennsylvania, and Kingston, New York.

Near Warfordsburg, Fulton County, the Mandata beds are fossiliferous, but *Eospirifer macropleurus* was not observed. This species is abundant in the underlying New Scotland limestone which may well have displaced the lower beds of the Mandata as seen at Mandata. The fauna observed in the Warfordsburg area includes *Leptostrophia beckii, L. oriskania*, the *Chonetes* n. sp. with pustulose ridges, found in the Port Ewen in Monroe County and at Kingston, together with *Octonaria* n. sp. suggesting *Thlipsurella multipunctata.*

Fossils are very scarce in the Mandata of the more westerly sections. Some questionable specimens, possibly *Anoplotheca concava*, were observed at Hollidaysburg.

Correlation with New York. The fauna of the lower half of the Mandata at Mandata and in Perry County, as previously listed, clearly shows that these lower beds are closely equivalent to the New Scotland of New York, and must be regarded as an extension from that formation. If they could be separated in a satisfactory manner from the overlying strata, they would be referred without hesitation to the New Scotland formation. This procedure may prove desirable with future work. (See Figure 17.)

The higher part of the Mandata in Perry County contains *Thlipsurella multipunctata* and other ostracoda of the Port Ewen, which will be described elsewhere. The fauna of the Mandata of Fulton County is also very suggestive of that of the Port Ewen. At the present time, then, the Mandata is believed to range from horizons of New Scotland age, which are seen in Northumberland and Perry Counties, to beds of Port Ewen age, at least in Perry and Fulton Counties. These relations are suggested in Tables XIII and XIV. Farther west the faunas are too poor for satisfactory correlation.

Although the Mandata appears to range from beds which are older to beds which are younger than the Becraft limestone of New York, it is notable that no typical Becraft species have been discovered in them within the areas above discussed. Accepting the correlations that have been suggested, the question arises, is absence of such a fauna due to an hiatus, or to some other factor? The answer is not clear at the present time.

LICKING CREEK LIMESTONE

General relations. The name, Licking Creek limestone, is here proposed for the late Helderbergian limestone, seen in bluffs along Licking Creek near Warren Point, Franklin County, Pennsylvania (see section, pp. 85-86). At this locality, it lies below the Ridgeley formation, containing the "*Spirifer*" *arenosus* fauna of the Oriskany group, and above a small thickness of calcareous shale and impure limestone, tentatively considered Mandata shale. The latter beds rest in turn upon New Scotland cherty limestone, containing a characteristic *Eospirifer macropleurus* fauna. (See Figure 17.)

The presence of this limestone at Licking Creek and at other localities east of Hancock, Maryland, was first recognized by R. B. Rowe.* Rowe obtained "*Spirifer*" *concinnus* and numerous other species from these beds, and concluded that they represent the "*Sieberella pseudogaleata* zone" of the Becraft limestone of New York. The formation was subsequently termed Becraft limestone by Schuchert (180).

The Licking Creek limestone contains, it is true, numerous species allying it with the Becraft of New York. As will be shown, however, it also contains species which indicate that it ranges considerably above the limits of that formation. Furthermore, recent studies lay further emphasis on the fact, first noted by Rowe, that the Licking Creek limestone can not well be considered a direct continuation of the type Becraft (see Figure 16). Thus, the Becraft limestone of New York thins and disappears southward in the Stroudsburg-Palmerton region of Pennsylvania (see Figure 17). It is reasonably certain that the Becraft and Licking Creek do not form a continuous limestone body through the present areas of Devonian outcrop in Pennsylvania. The possibility that they were originally connected southeast of this area seems remote in view of the considerations upon which the idea of the Auburn Promontory is here presented.

The Licking Creek limestone is believed to extend southward along a narrow belt to Monterey and Clifton Forge, Virginia (see Figure 16), where it was termed Becraft limestone by the writer in 1929 (208). The name, Long Dale limestone, was suggested in 1922 in a brief abstract by R. J. Holden (124), presumably for these same beds. Unfortunately, Holden's data were never published, and the occurrences near Long Dale have never been described. Because of these deficiencies in Holden's term, the writer believes it much more desirable to use the term Licking Creek, based upon Rowe's classical section.

Distribution. The Licking Creek limestone is known in Pennsylvania only in a small area at the southeastern tip of Franklin County (see Figures 16, 17).

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* Rowe, R. B., Paleodevonian Formations of Maryland, Dissertation, Library of Johns Hopkins University, 1900.

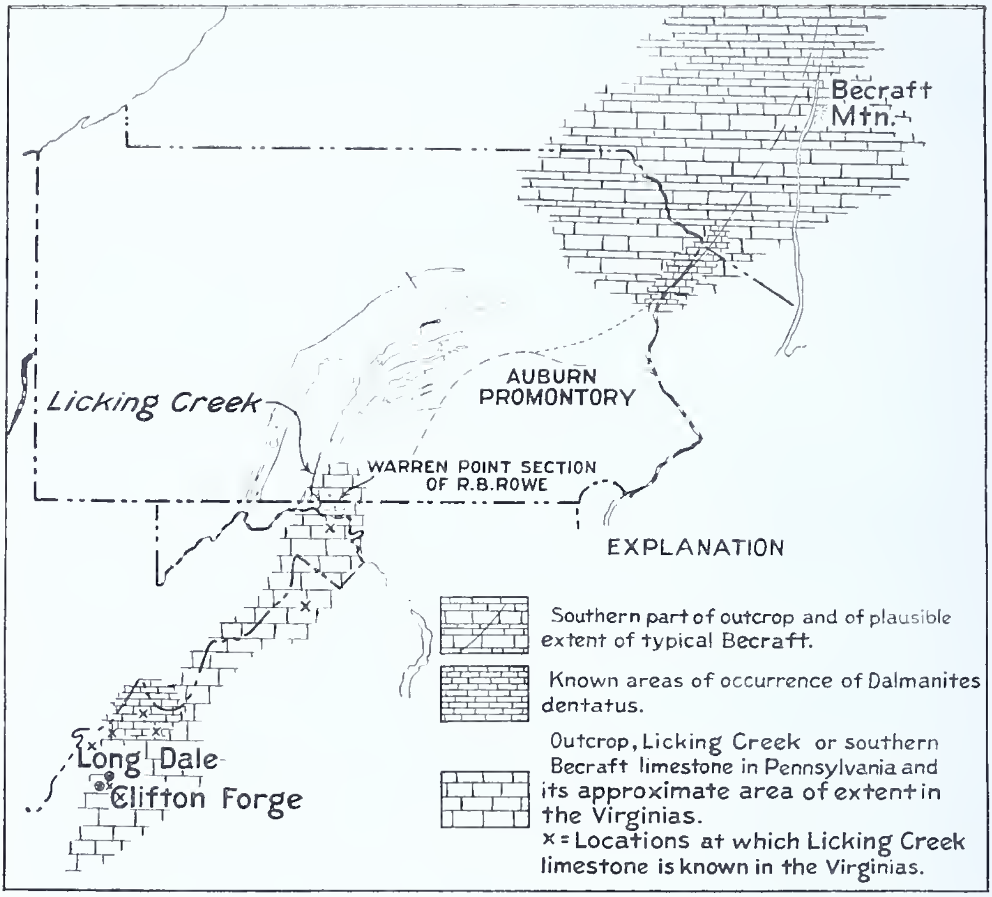
Becraft Mtn.
Licking Creek
AUBURN PROMONTORY
WARREN POINT SECTION OF R.B. ROWE
Long Dale
Clifton Forge
EXPLANATION
Southern part of outcrop and of plausible extent of typical Becraft.
Known areas of occurrence of Dalmanites dentatus.
Outcrop, Licking Creek or southern Becraft limestone in Pennsylvania and its approximate area of extent in the Virginias.
x = Locations at which Licking Creek limestone is known in the Virginias.

Figure 16. **Sketch map showing plausible geographic relations of the Becraft and Licking Creek limestones; also known areas of occurrence of *Dalmanites dentatus*.**

Lithologic features and thickness. The Licking Creek limestone is well exposed at the type locality in the bluff on the south side of Licking Creek, near Warren Point, Franklin County. This section was studied by R. B. Rowe in 1899. Interpreting his description in the light of recent studies, the formation exhibits the following divisions:

	Feet
Ridgeley sandstone	
Licking Creek limestone:	
Thick-bedded, light gray, chert-free, crystalline limestone. "*Spirifer*" *aroostookensis*, *Rensselaeria subglobosa*.	25
Light gray limestone, with numerous layers of black chert	20
Thick-bedded, light gray, crystalline limestone, with little chert. "*S.*" *concinnus (?)*, *R. subglobosa*.	25
Medium-bedded black chert; some limestone near top.	17
Mandata shale (?):	
Concealed; possibly Licking Creek; but these beds have been eroded back to form a continuous bench. Considered Becraft by Rowe and Schuchert.	35
Dark gray calcareous shale; *Octonaria thlipsurelloides* (undescribed) fauna not previously recognized.	4
New Scotland limestone, with *Eospirifer macropleurus* fauna.	

Part of the Licking Creek is also exposed on the north side of Licking Creek, east of the first section. The writer has not examined it elsewhere along its short line of outcrop in Pennsylvania.

Boundaries. In the exposures north of Licking Creek, the boundary between the Licking Creek and overlying Ridgeley sandstone is sharply defined by the sudden appearance of sand and fine gravel in the latter formation. The contact between the Licking Creek and Mandata (?) beds is not seen.

Economic value. The chert-free parts of the Licking Creek are satisfactory for agricultural lime and road material.

Fauna and correlation. As described by Schuchert, the fauna of the Licking Creek limestone at Warren Point and nearby localities in Maryland includes *Rhipidomella assimilis, Schuchertella woolworthana, Eatonia singularis, E. peculiaris, Plethorhynchus campbellana, Rensselaeria subglobosa, "Spirifer" concinnus, "S." cyclopterus, Cyrtina rostrata, Anoplotheca flabellites* (see plates). Among these species *Rensselaeria subglobosa* and *Cyrtina rostrata* occur in the *Dalmanites dentatus* zone of New Jersey, and are unknown in the type Becraft. Specimens collected by the writer show that much of the material hitherto regarded as *"Spirifer" concinnus* at Warren Point actually possesses the grooved ribs of *"S." aroostookensis* of the so-called Oriskany beds of Aroostook County, Maine, and Highland Mills, New York. The writer has also obtained at Warren Point material indistinguishable from *Leptostrophia blainvilli,* which occurs above *"Spirifer" arenosus* beds in the Gaspé region; also the *Chonetes* n. sp., with pustulose ridges, which occurs in the Port Ewen in Monroe County and New York.

The writer has recently obtained fragmentary but representative *Dalmanites dentatus,* with *Leptaena ventricosa* and *Leptostrophia magniventroides* n. sp., in Licking Creek limestone at Monterey, Virginia.* With these, as previously described, occur *Rensselaeria subglobosa, Cyrtina varia,* and large varieties of *"Spirifer" concinnus.*

The faunas listed above indicate that the Licking Creek, at least at Monterey, ranges up to the *Dalmanites dentatus* zone of New Jersey, and perhaps even higher. It apparently also includes beds equivalent to the Port Ewen and typical Becraft.

Dalmanites dentatus has not been recognized except in the type area through New Jersey and Trilobite Mountain, on the one hand, and Monterey, on the other (see Figure 16). Its migration from the one area to the other is not understood.

Relations of the Helderberg and Oriskany Groups in Pennsylvania

The interrelationships of the Helderberg and Oriskany groups in Pennsylvania are rather complex, and are not as yet wholly understood. Interpretations that appear most plausible with present knowledge are illustrated in Tables XIII and XIV. Further investigations will be required before the details can be fully clarified.

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* The important faunal differences in the limestones at Licking Creek and Monterey need further study.

The faunal sequence from the Helderberg to the Oriskany deposits is more complete in New Jersey and nearby localities than at most other places in the Appalachian area. The following zonal succession is largely based on work by Weller (223) in New Jersey and Shimer (192) at Trilobite Mountain, with some modifications by the writer:

Oriskany of Weller and Shimer	"*Spirifer*" *arenosus* zone, with "*S.*" *murchisoni* *Orbiculoidea jervensis* zone: *Metaplasia plicata* common here, rare in next overlying beds. *Dalmanites dentatus* zone, with *Rensselaeria subglobosa*, "*Spirifer*" *murchisoni*, "*S.*" *concinnus* var., *Cyrtina rostrata* (*varia?*).
Helderberg of Weller and Shimer	Port Ewen zone: "*Spirifer*" *concinnus* and "*S.*" *murchisoni* reported by Shimer and others; *Thlipsurella multipunctata* and other characteristic ostracoda obtained by writer. Becraft zone: "*Spirifer*" *concinnus* with numerous New Scotland species. New Scotland zone: *Eospirifer macropleurus* fauna (*E. macropleurus* also reported rare in Port Ewen). Coeymans zone: *Gypidula coeymanensis*.

In connection with descriptions of Lower Devonian ostracoda published in 1932 and 1936 (209, 211), the writer pointed out the occurrence in the middle part of the Shriver of central Pennsylvania, of a zone containing numerous *Metaplasia plicata*. The stratigraphic position and fauna of this zone, as understood by the writer, are illustrated by the appended descriptions of sections at Hollidaysburg and Lewistown, central Pennsylvania. The zone contains an *Orbiculoidea* believed to be *O. jervensis*. There are numerous ostracoda, of which *Bollia sagittaformis*, *B. burgeneri*, and *Acanthoscapha pentagonalis* appear to be confined to this zone, while *Thlipsurella secoclefta*, *Thlipsura confluens*, and *T. tricornis* are common in both these and higher parts of the Shriver. In the writer's opinion, this zone is a western extension of the *Orbiculoidea jervensis* zone of New Jersey, and is early Oriskany in age. (See Plates 8 and 9.)

In the sections at Hollidaysburg, Lewistown, and Curtin, satisfactory faunas have not been found between the *Metaplasia plicata* zone and lower lying New Scotland beds containing *Eospirifer macropleurus*. Farther to the east, however, the *Thlipsurella multipunctata* ostracode fauna of the Port Ewen occurs in the upper part of the Mandata shale at Clarks Mill in Perry County. The *Metaplasia plicata* zone is not found at this locality. *Eospirifer macropleurus* occurs in the lower part of the Mandata at Clarks Mill, and the Mandata is included in the Helderberg group.

Metaplasia plicata and most of the characteristic ostracoda associated with it in central Pennsylvania have not been observed as yet in the Shriver chert in its type area near Cumberland, Maryland. On the other hand, *Thlipsurella multipunctata* was originally described from the Shriver of the Cumberland area by Ulrich and Bassler. Thus the middle Shriver of central Pennsylvania is believed to be equivalent to the *Orbiculoidea jervensis* zone of the Oriskany of New Jersey; whereas the type Shriver may include beds of Port Ewen age. Further investigation of the ostracoda and other fossils of the Shriver of western Maryland is needed to throw light on these relationships.

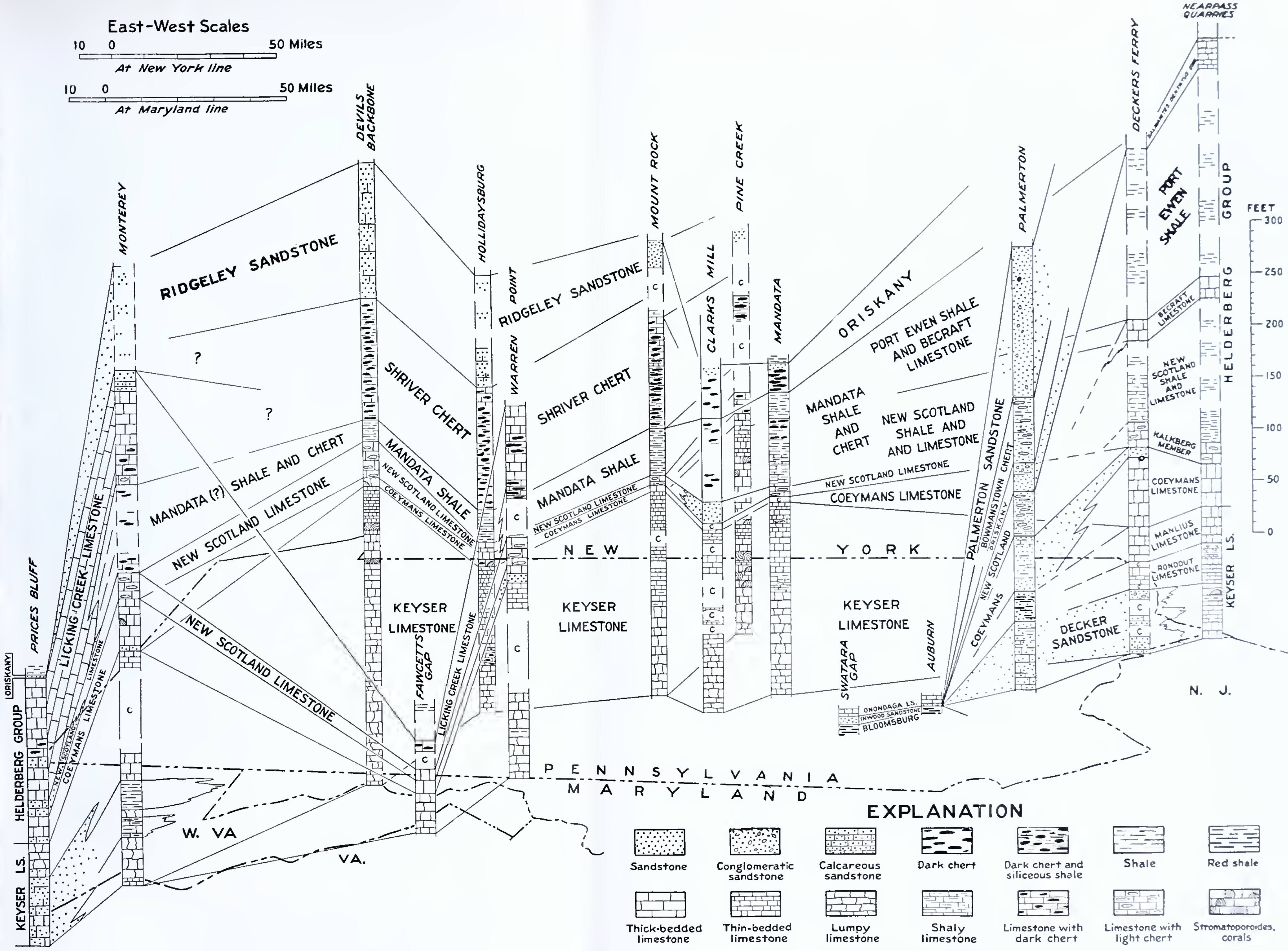

Figure 17. Correlation chart of the Keyser and Helderberg group from New Jersey to Virginia. Nearpass quarries after S. Weller; Warren Point after R. B. Rowe and C. Schuchert; Devils Backbone after C. K. Swartz, C. Schuchert and others; Palmerton, Auburn, Swatara Gap and Fawcetts Gap after C. K. and F. M. Swartz; Deckers Ferry, Mandata, Pine Creek, Hollidaysburg, Monterey and Prices Bluff after F. M. Swartz; Clarks Mill and Mount Rock, Keyser modified from Reeside, other beds mostly from F. M. Swartz.

Thlipsurella multipunctata was identified by Ulrich in the lower part of the beds here referred to the Mandata shale and chert at Tonoloway Ridge, Maryland, about 10 miles southwest of Warfordsburg, Pennsylvania. On the basis of the writer's collections, this is believed to be a new species of *Octonaria*, which also occurs below the Licking Creek ("Becraft") limestone at Warren Point.

The late Helderberg limestone at Warren Point is believed to be continuous to the south with the Licking Creek ("Becraft") limestone seen near Monterey and Clifton Forge, Virginia. Near Monterey, at least, this limestone in part contains *Dalmanites dentatus* and *Rensselaeria subglobosa*, and thus is believed to range as high as the *Dalmanites dentatus* zone of New Jersey. These *Dalmanites dentatus* beds are presumably older than the *Metaplasia plicata* zone of the Shriver of central Pennsylvania, judging from the faunal succession in New Jersey. Their relations to the type Shriver of western Maryland, where *Thlipsurella multipunctata* was first described, are not yet clear.

SELECTED SECTIONS OF THE KEYSER LIMESTONE AND HELDERBERG GROUP IN PENNSYLVANIA

Descriptions of a few representative sections of the Helderberg group are presented on the following pages, and their locations are indicated in Figure 7. The writer hopes to publish in the near future additional sections on which the accompanying discussions of the Keyser and Helderberg deposits are based.

SECTION 7: HALF A MILE EAST OF HOLLIDAYSBURG, BLAIR COUNTY, PENNSYLVANIA*

One of the finest exposures of Lower Devonian rocks in Pennsylvania is seen along the highway to Frankstown and Water Street, about half a mile northeast of Hollidaysburg, Blair County, Pennsylvania. The Keyser, Helderberg, and Shriver beds make a high bluff along the roadside at this place.

This section was described by the writer in 1929 (208; pp. 18-20). Ostracoda from the Shriver chert at this and other localities in central Pennsylvania were subsequently described in 1932 and 1936 (209, 211). The writer also has a collection of very interesting trilobites from the upper part of the Shriver at these localities, and expects to describe them in the near future. In order to record the occurrences of this material, a description of the Shriver is included here with that of the Keyser-Helderberg section.

	Feet Unit	Feet Total
DEVONIAN SYSTEM:		
ORISKANY GROUP:		
RIDGELEY SANDSTONE:		
Largely concealed, but with occasional exposures of thick-bedded calcareous sandstone.	70	105
Thick-bedded very fine-grained calcareous sandstone. Lower ten feet concealed along the highway but exposed along the railroad tracks below it. The beds seen along the highway contain "*Spirifer*" *murchisoni*, "*Spirifer*" *arenosus*, *Rensselaeria marylandica* and other Ridgeley fossils.	35	35

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* A new highway cut changes the apparent position of the faults and other details of the section as described.

	Feet	
	Unit	Total
SHRIVER CHERT:		
Thin- to medium-bedded dark highly siliceous impure limestone or calcareous impure chert, weathering to a light buff punky residue. Concealed 20 to 23 feet. Lower 20 feet make a rather prominent bluff at the roadside near the eastern end of the Shriver exposure. These are the upper Shriver trilobite beds. In upper 4 feet: *Actinopteria* cf. *A. virginica* (r), *Symphoria* sp. (r), *Thlipsura confluens* (c), *Thlipsurella secoclefta* (r) *T. oblonga* (r) In lower 20 feet: *Pholidops tumida* (c), *Schuchertella becraftensis* (r), *Chonetes hudsonicus* (c), *Metaplasia plicata?* (r), *Diaphorastoma desmatum* (c), *Symphoria* 2 n. sp. (a), *Cyphaspis* n. sp. (r), *Acidaspis (Leonaspis) tuberculatus* var. (r), *Paraschmidtella dorsopunctata* (r), *Pyxiprimitia ventriclefta* (c) *Parabolbina limbata* (r), *Bollia americana* (r), *B. americana* var. *zygocornis* (c), *B. cristata* (c), *Ulrichia pluripuncta* (c), *U. terminalis* (r), *Octonaria dorsosulcata* (r), *Thlipsura confluens* (a), *T. tricornis* (c), *Thlipsurella secoclefta* (r) *T. orthoclefta* (c), *T. oblonga* (c), *Tubulibairdia tubulifera* (c), *Cavellina paraquaesita* (c).	27	117
Thin-bedded to fissile dark siliceous shale grading into medium-bedded dark impure somewhat calcareous chert, breaking into blocky pieces, and weathering a darker brown than the overlying beds. Top not well marked; base well defined. The succession is disturbed by faults,* the shale member of the New Scotland being repeated near the middle of the outcrop of these strata. The *Metaplasia plicata* zone of the middle Shriver, as described by the writer in 1932 and 1936 (210, 212), is represented by the fauna obtained at 70 and 55 feet, as follows: *Pholidops tumida* (c) 55; *Chonetes hudsonicus* (c) 70; *Metaplasia plicata* (r) 70, (c) 55; *Bollia americana* (r) 70, (r) 55; *B. americana* var. *zygocornis* (r) 70; *B. sagittaformis* (r) 55; *B. burgeneri* (c) 55; *Thlipsura confluens* (c) 70, (c), 55; *T. robusta* (r) 70. (c) 55; *T. tricornis* (r) 55; *Thlipsurella secoclefta* (r) 70; *T. oblonga* (c) 70, (r) 55; *T. orthoclefta* (r) 70 (r) 55, *Tubulibairdia tubulifera* (c) 70, (c) 55; *Acanthoscapha pentagonalis* (c) 55. In central Pennsylvania, at least, the ostracoda *Bollia sagittaformis*, *B. burgeneri*, and *Acanthoscapha pentagonalis* are characteristic of and are known only in the *Metaplasia plicata* zone. The writer has not obtained faunas, except for a few specimens of *Anoplotheca flabellites*, in the lower 40 to 50 feet of the Shriver in the area.	90	90
HELDERBERG GROUP:		
MANDATA SHALE:		
Dark splintery to fissile, somewhat calcareous shale. Somewhat fossiliferous, but determinable specimens are hard to obtain. Cf. *Anoplotheca concava* (c).	31	41
NEW SCOTLAND LIMESTONE:		
Thick-bedded finely crystalline gray limestone, with some interbedded chert, weathering light-colored, in upper 6½ feet, and with 1 foot of interbedded shale and thin-bedded limestone at base. *Eospirifer macropleurus* fairly common in upper 6 or 7 feet. At 4 to 6 feet: *Rhipidomella oblata* (a), *Isorthis perelegans* (c), cf. *Leptostropha planulata* (c), *L. bekii* (c), *Schuchertella woolworthana*, large (a), *Chonetes* sp. (r), *Eospirifer macropleurus* (r), "*Spirifer*" *perlamellosus* (c), *Phacops logani* (c).	10	10

---

* A new highway cut changes the apparent position of the faults. (?)

	Feet Unit	Feet Total
COEYMANS LIMESTONE:		
Thick-bedded gray crystalline limestone, with a few interbedded lenses of dark chert in the upper five feet. The contact with the underlying dense limestones of the upper Keyser, which weather buff or dove-colored as compared to the more bluish gray of the Coeymans, is very sharp, and somewhat irregular. The basal 3 to 4 inches of the Coeymans contain occasional fragments of dense limestone of upper Keyser type. The contact is evidently disconformable. *Favosites* cf. *F. helderbergiae* (c); *Gypidula coeymanensis* (r) 2 inches above base. (a) in middle part, (r) in upper 5 feet.	13½	13½
SILURIAN SYSTEM:		
KEYSER LIMESTONE:		
Laminated drab blue dense limestone, in part weathering dove-gray or somewhat yellowish. Mud cracks occur on several bedding planes. These beds are very suggestive of the Tonoloway limestone. The beds are considerably disturbed by minor faults.	36	140
Medium-bedded dense blue limestone, 3½ feet, above; thinly laminated more impure limestone, below. Cf. *Leperditia gigantea* (aa) at top, (c) 1 to 2 feet above base.	7	104
Medium- to thin-bedded dark drab dense limestone, somewhat shaly near the base, and with some thin partings of shale at higher levels. *Rensselaeria mutabilis* sub-zone: "*Spirifer*" *vanuxemi* (a), *Rensselaeria mutabilis* (r) in upper 3 feet. *Pholidops ovata* sub-zone: *Pholidops ovata* (aa), "*Spirifer*" *vanuxemi* (r), 10 feet above base.	23	97
Thick-bedded dark gray, finely crystalline to dense somewhat lumpy limestone. *Merista typa* sub-zone with *Calymene camerata*, *Atrypa reticularis* (a) *Tentaculites gyracanthus* (r) at top; *Merista typa* (a), *Calymene camerata* (a) 1 to 2 feet below top; *Orthoceras* sp. (r) below.	5	74
Thin- to medium-bedded dark drab dense limestone, in layers 2 to 3 inches thick, with thin partings of argillaceous limestone or calcareous shale. Many lenses of dark chert follow the bedding of the limestone layers. *Atrypa reticularis* (a) 15 feet above base.	22	69
Thick-bedded drab gray dense to finely crystalline impure limestone, somewhat lumpy when weathered.	21	47
Thick-bedded finely crystalline limestone. Bryozoa (aa), *Atrypa reticularis* (aa), "*Spirifer*" *octocostatus* (a).	4	26
Thick-bedded drab blue dense to finely crystalline limestone, weathering into lumpy masses, the lower 7 feet very shaly. The succession is much disturbed by minor faulting. *Stenochisma deckerensis* subzone. The following fossils were found loose at the outcrop of these beds near the top of the bluff: cup corals (c). cf. *Rhipidomella emarginata* (r). *Leptaena rhomboidalis* (c), *Stenochisma deckerensis* (a), *Atrypa reticularis* (a), "*Spirifer*" *octocostatus* (c)	12	22
Thick-bedded drab gray finely crystalline limestone. A 14-inch bed 2½ to 3½ feet above base weathers with a peculiar arrangement of pits. The contact with the next underlying beds is somewhat suggestive of a disconformity.	10	10
TONOLOWAY LIMESTONE:		
Thick-bedded drab gray dense limestone; upper part with some irregular lamination.	4	87

	Feet Unit	Feet Total
Thinly laminated, drab blue dense limestone, weathering light gray and becoming platy. Layers and lenses of dark chert follow the bedding at 10½, 16½, 18½, 19, and 22 feet above the base.	32½	83
Thin-bedded dove gray dense limestone: at top a 6-inch bed of dense limestone, with much crystalline quartz. Seen at top of entrance to small cave.	1½	50½
Thick-bedded dense limestone, much fractured in an irregular fashion.	2	49
Thin-bedded mostly laminated drab gray dense limestone, weathering light bluish gray. Several layers of chert 20½ to 23 feet above base. Some edgewise limestone conglomerate in upper 1½ feet. Lower part seen along gutter.	47	47
Concealed to west.		

SECTION 6: AT MOUNT ROCK, NEAR LEWISTOWN, MIFFLIN COUNTY, PENNSYLVANIA

Keyser, Helderberg, and Oriskany beds are exposed along the road on the west side of Kishacoquillas Creek, in the northern outskirts of Lewistown, Pennsylvania, opposite the small settlement known as Mount Rock. The horizon 42 feet above the base of the Keyser as here described, is 218 feet north of the middle of the entrance to the bridge leading to Mount Rock. The Oriskany beds are exposed south of the bridge entrance. The section is about 110 yards south of the abandoned trolley barn, seen along the present main highway from Lewistown to Highland Park and Burnham. The Keyser and Helderberg rocks of this section were described by Reeside in 1917 (167; pp. 212-214). The basal 42 feet of the Keyser as here described were included in the Tonoloway by Reeside. The faunas of the Keyser-Helderberg beds are based on Reeside's work, except in the case of these lower beds. The upper Keyser, Coeymans, and New Scotland are much overgrown at the present time. They are seen to better advantage in exposures at Painterville, about 7 miles northeast of Lewistown.

The Shriver chert was measured by the writer with the assistance of Glen Burgener, who studied some of the collections for his undergraduate thesis. Additional material was subsequently obtained, and the Shriver sections here and at Hollidaysburg were written up for a paper published in 1936 (211), but were not included. Description of the Shriver here and at Hollidaysburg is included in this chapter, since many of the Shriver ostracoda described by the writer (209, 211) were obtained at these localities.

DEVONIAN SYSTEM:

ORISKANY GROUP:

Ridgeley Sandstone:	Feet Unit	Feet Total
Thick-bedded rather coarse-grained calcareous sandstone, containing "*Spirifer*" *arenosus* fauna.	25	65
Concealed. Part or all of this interval may belong in the Shriver chert.	40	40

Shriver Chert:

Medium- to thick-bedded very siliceous limestone or calcareous chert, weathering buff and punky, at top; grading

	Feet	
	Unit	Total
downwards into thin- to medium-bedded dark calcareous impure chert and siliceous shale, weathering in part to a darker brown. The trilobite zone of the upper Shriver of central Pennsylvania occurs in the upper 10 feet of these beds. The *Metaplasia plicata* zone, with *Orbiculoidea jervensis?*, *Bollia sagittaformis*, *B. burgeneri*, and *Acanthoscapha pentagonalis*, occurs in the lower 40 to 50 feet. The trilobite-bearing fauna was collected at 110 to 105 feet, as follows: *Edriocrinus* near *E. sacculus*, but small, (r); *Platyorthis planoconvexa* and var. with very large cardinal process (c); *Leptostrophia oriskania* (c); *Brachyprion schuchertanum*, externally punctuate (c); "*Spirifer*" *murchisoni* (a); "*S.*" *tribuarius?* (c); *Megalanteris ovalis* (r); *Meristella* sp. (c); *Diaphorastoma desmatum* (c); *D. ventricosum?* (r); *Tentaculites elongatus (T. reedsi?)* (c); *Acidaspis (Leonaspis) tuberculatus* var. (r); *Symphoria* n. sp. (c); *Bollia americana* and var. *zygocornis* (c), *B. cristata* (c); *Thlipsurella secoclefta* (c). The *Metaplasia plicata* fauna was collected in underlying beds as follows: *Pholidops tumida* (c) 78-70, (?c) 67, (c) 63-61: *Orbiculoidea jervensis?* (a) 75-70, (r) 58-52; *Platyorthis?* sp. (r) 90-91; *Schizophoria* cf. *S. multistriata* (r) 90-91; *Camarotoechia* sp. (c) 90-91: "*Spirifer*" cf. "*S.*" *cyclopterus*, concentric lamellae too close set for "*S.*" *tribulis* (c) 90-91; *Metaplasia plicata* (c) 87-84, (c) 78-75, (a) 75-70, (c) 67, (r) 63-61, (r) 58-52; *Anoplotheca dichotoma* (aa) 98; *A. flabellites* (c) 87-84; *Megalanteris immatura* (c) 91-90, (c) 87-84, (c) 78-75; *Tentaculites elongatus (T. reedsi?)* (c) 87-84, (aa) 78-75; *Parabolbina limbata* (r) 70; *Bollia americana* and var. *zygocornis* (c) 78-75, (r) 75-70, (c) 67; *Bollia sagittaformis* (r) 98, (r) 91-90; *B. burgeneri* (r) 90-91, (c) 78-75, (c) 75-70, (c) 67; *Kirkbyella? ventricosa* (r) 90; *Thlipsura confluens* (c) 87-84, (c) 75-70, (c) 67, (c) 63-61; *T. robusta* (r) 67; *T. tricornis* (r) 98; *Thilipsurella secoclefta* (c) 75-70; *T. orthoclefta* (c) 75-70, (c) 67; *Acanthoscapha pentagonalis* (c) 75-59; *Tubulibairdia tubulifera* (c) 87-61.	65	114
Thin-bedded to blocky highly siliceous somewhat calcareous shale and much thin-bedded dark impure chert, the chert not exhibiting a typical cherty luster. *Anoplotheca flabellites* (r) 48, 19.	40	49
Highly siliceous somewhat calcareous shale or impure chert, weathering blocky.	9	9
HELDERBERG GROUP:		
MANDATA SHALE:		
Somewhat siliceous shale, blocky below, thin-bedded to fissile above. Possibly Shriver.	10	44
Fissile shale, partly concealed in upper part, but upper 2 feet exposed.	34	34
NEW SCOTLAND LIMESTONE:		
Thick-bedded gray finely crystalline limestone and some interbedded chert; 9-inch bed of shale in upper part. In upper half: *Rhipidomella oblata*, *Isorthis perelegans*, *Leptostrophia beckii*, *Schuchertella woolworthana*. *Chonostrophia helderbergiae*, *Eatonia medialis*, *Atrypa reticularis?*, *Eospirifer macropleurus* (a), "*Spirifer*" *perlamellosus*. In lower half: *Isorthis perelegans*, *Leptostrophia planulata?*, *Eatonia medialis*.	5	9½

	Feet	
	Unit	Total
Thick-bedded light gray limestone and interbedded chert, with 6 inches of brown shale at top. These and the next underlying beds were included in the Coeymans by Reeside, who reported the following fauna: *Stropheodonta arata*[*] *Schuchertella* sp., *Gypidula coeymanensis*, *Atrypa reticularis*, *Meristella* sp. The writer did not find *Gypidula coeymanensis* in the corresponding beds at Painterville, and is tentatively including these strata in the New Scotland. If the identification of *Gypidula coeymanensis* at this horizon is not an error, Reeside's classification would be correct.	3	4½
Dark gray calcareous shale and interbedded thin layers and large nodules of limestones. *Lingula* sp., *Leptaena rhomboidalis*, *Leptostrophia planulata?*, *Schuchertella woolworthana*, *Chonetes* sp., *Orthoceras* sp., ostracoda near top.	1½	1½
COEYMANS LIMESTONE:		
Thick-bedded crystalline blue limestone, somewhat arenaceous; some nodules of black chert. At 5½ feet: *Isorthis perelegans?*, *Leptaena rhombodalis*, *Gypidula coeymanensis*, "*Spirifer*" *cyclopterus*. 3 to 2 feet: *Pholidops ovata*, *Rhipidomella oblata*, *Stropheodonta arata*, *Strophonella leavenworthana*, "*Spirifer*" *cyclopterus*, *Phacops logani*, *Dalmanites* sp.	6	6
SILURIAN SYSTEM:		
KEYSER LIMESTONE:		
Thin-bedded dense dark limestone. *Leperditia* sp.	1	196
Thick-bedded dark gray dense limestone, 1 foot of shaly limestone, weathered yellow, at middle.	5½	195
Shale.	2	189½
Dense limestone, lower 3 feet platy.	4	187½
Concealed, with 2 feet of platy limestone at middle.	13	183½
Impure platy limestone weathering yellowish.	8	170½
Dense limestone, thick-bedded above, in two-inch layers below.	2½	162½
Concealed.	16½	160
Concealed below; 6 inches of banded dense limestone at top. *Meristella* sp., *Tentaculites gyracanthus*.	1½	143½
Thin-bedded dense to finely crystalline dark gray impure limestone. The *Rensselaeria mutabilis* zone occurs in these and underlying beds. In upper 6 feet: Bryozoa, *Pholidops ovata*, *Schuchertella interstriata?*, *Uncinulus keyserensis*, *Meristella* sp., *Rensselaeria mutabilis*, *R. obtusa*, *R. keyserensis*, pelecypoda, *Tentaculites gyracanthus*, *Orthoceras* cf. *O. pauciseptum*. In lower 4 feet: *Dalmanella* sp., *Schuchertella prolifica*, *Beachia proavita*, *Tentaculites gyracanthus*.	10½	142
Concealed.	6	131½
Shaly limestone, with thin purer layers. *Pholidops ovata*, *Dalmanella concinna*, *Uncinulus keyserensis*, "*Spirifer*" *vanuxemi* var. *prognosticus*, *Beachia proavita*.	3	125½
Light blue-gray coarsely nodular shaly limestone. *Uncinulus keyserensis*, "*Spirifer*" *vanuxemi* var. *prognosticus*, *Rensselaeria keyserensis*.	3	122½
Thin-bedded gray crystalline limestone. *Pholidops ovata*, "*Spirifer*" *vanuxemi* var. *prognosticus*, *Rensselaeria mutabilis*.	3	119½
Thin-bedded finely crystalline blue gray limestone; upper 2½ feet thick-bedded. 6 feet above base: *Pholidops ovata*, *Dalmanella concinna*, *Atrypa reticularis*, *Merista typa*.	9½	116½

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[*] It is probable that Reeside's material was *S. varistriata*, not *S. arata*.

	Feet	
	Unit	Total
Impure shaly limestone, with interbedded harder layers. Concealed 2 to 6 feet above base. 1 foot below top: *Pholidops ovata, Rensselaeria mutabilis.* Near base: *Dalmanella concinna, Leptaena rhomboidalis, Stropheodonta bipartita, Camarotoechia litchfieldensis, Atrypa reticularis, "Spirifer" vanuxemi* var. *prognosticus.*	9½	107
Dark gray crystalline limestone. *Stropheodonta bipartita, Merista typa, Rensselaeria mutabilis, Calymene camerata.*	5	97½
Thin-bedded limestone and calcareous shale. *Leptaena rhomboidalis, Stropheodonta bipartita, Schuchertella deckerensis, "Spirifer" vanuxemi, Merista typa, Calymene camerata.*	6	92⅛
Thick-bedded lumpy impure limestone. *Gypidula coeymanensis, Merista typa* near base.	7	86½
Thick-bedded scarcely nodular impure limestone. The base of this bed is 180 feet north of middle of entrance to bridge to Mount Rock. This and adjacent beds contain the *Gypidula prognostica* subzone. *Orthostrophia strophomenoides?, Gypidula prognostica* (a), *Stenochisma* sp., *"Spirifer" octocostatus, Merista typa, Atrypa reticularis.* The top of this bed is believed to be 40.6 of the Keyser section as described by Reeside.	3½	79½
Thick-bedded lumpy finely crystalline to dense argillaceous limestone. Weathered surfaces in part rutted parallel to the bedding. Rather coarsely crystalline and somewhat less lumpy 4½ to 6½ feet above base. In upper 5 feet: *Rhipidomella emarginata, Dalmanella clarki, Leptaena rhomboidalis, Strophonella geniculata, S. leavenworthana?, Schuchertella deckerensis, Stenochisma deckerensis, Gypidula prognostica, Atrypa reticularis, Nucleospira* sp., *Goldius barrandi, Cyphaspis* sp., *Calymene camerata.* In lower 5 feet: *Stropheodonta bipartita, Schuchertella deckerensis, Chonetes jerseyensis, Stenochisma deckerensis, Atrypa reticularis.*	16	76
Medium to thick-bedded coarsely crystalline gray crinoidal limestone, not lumpy.	12	60
Thick-bedded dark blue finely crystalline limestone, weathering blue-gray, lumpy. Lowest foot thin-bedded. *"Spirifer" modestus* near base.	6	48
Thin-bedded dense to finely crystalline dark blue limestone; in part appears thick-bedded where not much weathered, but after weathering breaks into beds 1 to 2 inches thick. These are the lowest beds exposed directly along the roadside. They were included in the Tonoloway limestone by Reeside. Their top is 218 feet north of middle of entrance to bridge leading to Mount Rock. *Leperditia scalaris, Zygobeyrichia barretti* are common at numerous horizons.	20	42
Thick-bedded dense to finely crystalline dark blue limestone; somewhat lumpy, especially 3½-6½, 9-13 feet above base. *Leperditia scalaris* common at numerous horizons.	22	22
TONOLOWAY LIMESTONE:		
Concealed. (Keyser?).	4	28
Thinly-laminated mostly dense dark drab limestone. In part weathers platy; in part is tan-colored and earthy on broken surface. Exposed to west of road, beside old building used as a garage.	24	24
Concealed.		

SECTION 5: NEAR MANDATA, NORTHUMBERLAND COUNTY, PENNSYLVANIA

Keyser, New Scotland, and Oriskany beds are well exposed along the highway to Berrysburg, about ¼ mile south of Mandata (Bull Run), and about 4 miles northeast of Dalmatia, Northumberland County, Pennsylvania, in the area of the Millersburg Quadrangle of the U. S. Geological Survey. The section is at the western end of one of a line of knolls made by the Oriskany, Helderberg and Keyser beds. The lower Keyser is almost continuously quarried along this knoll, the quarry rock including both the *Leperditia scalaris* beds and parts of the overlying lumpy limestone.

White (229) described the occurrence of 8 feet of Stormville sandstone at the base of the Stormville shale at the Emrick and Lebo quarry near Bull Run (Mandata). Reeside (167; p. 217) stated that a sandy limestone 6 feet thick occurs at the quarry, is overlain by shale carrying *Eospirifer macropleurus*, and is probably Coeymans in age. One of the quarries in the knoll just east of the highway section is reported to be the old Emrick quarry, and may be the quarry referred to by White and Reeside. Some loose sandstone was seen on the bank above the hanging wall of this quarry, but no Coeymans fossils were observed in it. No Coeymans beds were located near the quarries by the writer, and in the highway section the Coeymans horizon is unfortunately covered. There are, however, some thin sandy layers and laminae in the uppermost Keyser.

The following section was measured along the highway.

DEVONIAN SYSTEM:

	Feet Unit	Feet Total
ORISKANY GROUP:		
Dark, relatively pure chert in layers 6 to 12 inches thick. The cherts tend to weather whitish, and evidently correspond to the whitish cherts occurring below fossiliferous Oriskany sandstone beds in the sections near Dalmatia.	19	19
HELDERBERG GROUP:		
MANDATA SHALE AND CHERT:		
Thin-bedded shale, weathering yellowish to greenish. Base and top concealed. No fossils observed; age uncertain.	24	91
Medium-bedded impure dark chert and interbedded dark gray shale. A 6- to 9-inch bed of impure limestone at 7 feet. Chert predominant 11½ feet to 20 feet above base. *Pholidops* sp. (c) 58; *Levenea subcarinata* (c) 75, (c) 58; *Leptaena rhomboidalis* (c) 75; *Leptaenisca concava* (c) 75, (c) 68; *Leptostrophia beckii* (c) 75, (c) 68; *Strophonella punctulifera* (r) 75; *Eatonia singularis* (c) 75; *Uncinulus* sp. (r) 75; "*Spirifer*" *cyclopterus* and var. (*aa*) 75, (a) 58; "*S.*" *perlamellosus* (a) 75, (c) 68, (r) 58; *Cyrtina dalmani* (r) 75, (r) 58; *Atrypina imbricata* (c) 75; *Trematospira multistriata* (c) 75, (r) 58; *Anoplotheca concava* (a) 75, (aa) 58; *Meristella* sp. (c) 75; *Rensselaeria* sp. (r) 75; *Tentaculites* sp. (r) 58; *Dalmanites* sp. (r) 113; *Beyrichia* n. sp. (r) 58; *Amphissites* sp. (c) 58; *Thlipsura* n. sp. (r) 58.	20	67
Thin-bedded dark gray shale, weathering greenish to brown, and a few interbedded layers of very impure chert. *Pholidops* sp. (c) 45; *Levenea subcarinata* (c) 45; *Leptaena rhomboidalis* (c) 42; *Eatonia medialis* (c) 45, (c) 42; *E. singularis*		

	Feet	
	Unit	Total
(c) 45; *E. peculiaris* (r) 45; *Eospirifer macropleurus* (c) 45, (c) 42; "*Spirifer*" *cyclopterus* (a) 45, (c) 42; *Atrypina imbricata* (r) 45; *Anoplotheca concava* (c) 45, (a) 42.	14½	47
Thin-bedded gray shale, weathering greenish brown, and 4 interbedded layers of dark gray finely crystalline limestone, the third layer from base 12 to 16 inches thick. At top is a 3- to 6-inch layer of dark chert, resting on the topmost limestone bed. At 37½ feet: cf. *Leptaenisca concava* (r), *Leptostrophia beckii* (c), *Eatonia medialis* (r), *Eospirifer macropleurus* (a), "*Spirifer*" *cyclopterus* (c), *Anoplotheca concava* (a) cf. *Trematospira equistriata* (r), *Meristella* sp. (c).	8½	32½
Thin-bedded shale weathering greenish; a 4-inch bed of impure limestone at 5 feet. At 21 to 23 feet: *Lerenea subcarinata* (c), *Leptostrophia beckii* (c), *Schuchertella woolworthana* (c), *Eatonia medialis* (a), *E. singularis* (r), *Eospirifer macropleurus* (c), "*Spirifer*" *perlamellosus* (c).	20	24
Concealed.	4	4
NEW SCOTLAND LIMESTONE:		
Thick-bedded crystalline blue gray fossiliferous limestone, partly concealed. A 4- to 8-inch layer of chert at 5½ feet above base. *Eospirifer macropleurus* not seen in place, but occurs on loose slabs of the chert. At 5 feet: *Streptelasma?* sp. (c), fenestellid and branching bryozoa (c), *Isorthis perelegans* (a), "*Spirifer*" *cyclopterus* (c), *Rhynchospira formosa* (r), *Actinopteria?* sp. (r), *Phacops logani* (a).	9	9
COEYMANS LIMESTONE (?):		
Concealed. Coeymans beds may be present in this interval, but have not definitely been located in the Dalmatia-Mandata area.	6	6
SILURIAN SYSTEM:		
KEYSER LIMESTONE:		
Thin-bedded blue finely crystalline to dense limestone. Some thin-bedded calcareous shale 1½ to 3 feet above base. Beds above the shale are in part laminated and weather platy. In part, there are thin sandy laminae which show in relief on the weathered surface. At top is a 1-inch layer of medium grained calcareous sandstone, containing *Leperditia* sp. Leperditias also occur at 37 feet. It is possible that these beds represent part of the sandy limestone reported by White and Reeside; but both the lithology and the leperditias indicate that they are Keyser and not Coeymans in age.	8½	39
Concealed.	5½	30½
Thin- to medium-bedded gray finely crystalline impure limestone. A ½-inch layer of dark chert 2½ feet above base. Beds 3 to 9 feet are largely laminated and weather platy.	9	25
Concealed.	10	16
Thin- to medium-bedded blue gray finely crystalline, in part laminated limestone.	6	6
Concealed for some distance to south. Mouth of a highway culvert about 70 feet south of the measured section. Lumpy Keyser limestones are exposed for some distance south of the culvert. A road leads west from the highway about 300 feet farther south.		

SECTION 4: AT CLARKS MILL, PERRY COUNTY, PENNSYLVANIA

The upper Tonoloway and Keyser limestones are fairly well exposed, together with a skeleton section of overlying New Scotland and Oriskany beds, along the highway to Marklesburg, about ⅛ mile north of McKee and 2 miles northwest of New Bloomfield, Perry County, Pennsylvania, within the New Bloomfield Quadrangle of the U. S. Geological Survey. The section is just opposite the old Clarks Mill, which stands at the intersection of the highway with a road branching to the west. It is along the right of way of the defunct Newport & Sherman Valley Railroad.

This section was described in 1885 by Claypole (72; p. 182). He recognized below the Oriskany sandstone and "yellow flint shale," black cherty limestone 8 feet, Clark's Mill lime shales 150 feet, Lewistown limestone, 100 feet. In 1913, C. K. Swartz (204; p. 105) pointed out the Keyser age of Claypole's "Clark's Mill shales," the Tonoloway age of his Lewistown limestone. The Keyser and Tonoloway beds were described by J. B. Reeside, Jr., in 1917 (167; pp. 214-216). The thickness of the Keyser according to Reeside is 140 feet; using the traverse method, the writer has obtained 175 feet. It is clear, however, that both Reeside and the writer have placed the top and base of the Keyser at the same horizons. The difference in measurement is probably due to the fact that the numerous concealed intervals make it difficult to determine the thickness with a ruler. Because of the differences in details, it has not been possible to fit Reeside's extensive identifications of fossils into the section here given.

DEVONIAN SYSTEM:

Feet
Unit Total

ORISKANY GROUP:

Mostly covered; but with a finely conglomeratic sandstone, the quartz pebbles ⅛ to ¼ inch in diameter, in lower 2 feet; much loose chert, weathered whitish, and some sandstone to 810 feet traverse; much loose finely conglomeratic sandstone to 855 feet traverse. The cherts contain a *Chonostrophia complanatus*, "*Spirifer*" *murchisoni* fauna.

HELDERBERG GROUP:

MANDATA SHALE AND CHERT:

Mostly concealed. Beginning at 650 feet traverse there is much impure chert, weathered yellowish or purplish and punky, slumped but embedded in yellowish to reddish and some whitish residual clay. The cherts appear to be definitely in place 677 to 688, 760 to 769, 778 to 782, and 788 to 791 feet traverse. Traverse N21°E to 791 feet; highway culverts at 685 and 778½ feet traverse. Brachiopods are rare in these impure cherts at this locality, but ostracoda are common: *Schuchertella* sp. small (r) 90; *Tentaculites* sp. (r) 90; *Acidaspis* sp. (r) 52; *Aechmina* n. sp. (r) 90; *Pyxiprimitia* sp. (r) 90; cf. *Parabolbina granosa* (r) 87; *Bollia zygocornis* (r) 87; *Bollia cristata* var. (r) 63; *Thlipsura* n. sp. near *T. robusta* (r) 52, (c) 63, (r) 70, (c) 90; *Thlipsura dawsi* n. sp. (c) 81, (r) 87; *Thlipsurella multipunctata* (c) 52, (r) 63, (c) 70, (r) 81, (c) 87, (c) 90; *T. lachrymosa* n. sp. (r) 70, (c) 87, (r) 90: *Tubulibairdia tubulifera* (c) 63, (c) 70; *Cavellina?* sp. (r) 90. These ostracoda correspond closely to those of the Port Ewen at Experiment Mills, Pennsylvania, and near Kingston, New York. Cherts in the middle and

	Feet	
	Unit	Total
lower part of this interval contain *Eospirifer macropleurus* near Markle School, about 1 mile west of Clarks Mill, and at Falling Springs.	80	80
NEW SCOTLAND FORMATION:		
Falling Springs sandstone member:		
Concealed, with much loose fairly coarse grained sandstone, grading in part into whitish chert. The sandstone contains *Rhipidomella oblata* (c), *Schuchertella woolworthana* (c), *Eatonia medialis* (c), *Eospirifer macropleurus* (a), "*Spirifer*" *perlamellosus* (c). Thickness of the sandstone at this locality is uncertain; at Falling Springs 23 feet are exposed	20±	20±
COEYMANS LIMESTONE (?):		
Concealed, with much loose chert and some sandstone in residual clay. The sandstone and some of the chert are evidently loose from the overlying beds; some of the chert is thin-bedded, gray, and may belong here. Loose crinoid stems are numerous; *Gypidula coeymanensis* is common. Traverse N21°E to 570 feet.	7±	7±
SILURIAN SYSTEM:		
KEYSER LIMESTONE:		
Laminated impure limestone, weathering platy, gray. N78°E, 33°NW. Traverse N21°E to 553 feet.	5	175
Thin- to medium-bedded finely crystalline dark gray limestone, with thin beds of dark chert in upper 5 feet. Top at traverse N21°E 543 feet along roadside, drop 5 feet to road level. These and next underlying 29 feet of beds were measured by ruler on bank of old quarry pit, a little east of the line of traverse. Reeside reports *Schuchertella prolifica*, *Meristella praenuntia*, *Tentaculites gyracanthus* at top and base.	7	170
Concealed.	11	163
Thin- to medium-bedded dark blue dense to finely crystalline limestone, with many lenticular fossiliferous beds abounding in *Meristella praenuntia*. *Tentaculites gyracanthus*. Beds containing profuse meristellas are especially prominent 12 to 14 and 17 to 18 feet; beds 4 to 6 feet above base contain Bryozoa (c), *Meristella praenuntia* (aa), *Pelecypoda* (c), *Tentaculites gyracanthus* (aa), *Kloedenella* sp. Reeside reports *Orbiculoidea discus* (a) 8-3 feet below the cherts at 165 to 170 feet of this secton.	18	152
Concealed; base of overlying limestones projects to about 455 feet of traverse beside road. Reeside reports the *Rensselaeria mutabilis* fauna on loose slabs.	33	134
Mostly concealed, with a 4-inch bed of dense barren limestone at 377 feet, and with 1 to 2 feet of medium- to thin-bedded impure limestone, containing a great profusion of small branching bryozoa, at top. Some fissile greenish shale loose in upper part. The upper limestone also contains *Uncinulus* sp., large, (c), "*Spirifer*" *vanuxemi* (c), *Thlipseurella* n. sp. (c). This limestone is probably the 1 foot bed, crowded with a ramose bryozoan, at 97.4 to 98.4 feet of Reeside's section. Traverse N21°E to 388 feet. N79°E, 36°NW.	12	101

	Feet	
	Unit	Total
Fissile calcareous shale, weathering greenish, and some thin beds of argillaceous drab gray limestone, partly concealed. Traverse N21°E to 363 feet.	2	89
Concealed below, with a 6-inch bed of hard finely crystalline dark blue limestone at top. Traverse N21°E to 359 feet.	11	87
Thin-bedded dense to finely crystalline dark blue somewhat lumpy argillaceous limestone; with several thin lenticular beds of finely crystalline blue limestone, and with thin partings of calcareous shale. Lower 1½ feet concealed. Traverse N21°E to 335 feet. N77°E, 36°NW.	4	76
Thin-bedded finely crystalline dark blue limestone, partly concealed. Upper 2 to 3 feet abounding with bryozoa of massive and ramose types. Traverse N21°E to 326 feet.	8	72
Dark gray finely crystalline, extremely lumpy argillaceous limestone, weathering out in small rounded nodules commonly 1 to 2 inches in diameter. Upper 3 feet less lumpy than the remainder. Traverse N13°E to 309 feet.	14	64
Thin-bedded, in part somewhat lumpy, finely crystalline to dense dark limestone, with thin partings of greenish calcareous shale. Traverse N13°E to 283 feet. N69°E, 37½°NW. Near base: *Stenochisma deckerensis* (c), *Rhynchospira globosa* (a). In these beds, Reeside reports *Sphaerocystites multifasciatus*, *Chonetes jerseyensis*, *Camarotoechia litchfieldensis*, *Stenochisma lamellata*. *S. formosa*, "*Spirifer*" *modestus*, "*S.*" *modestus* var. *plicatus*, *Rhynchospira globosa*, ostracoda.	20	50
Thin, irregularly bedded, more or less lumpy dark blue dense limestone, somewhat less argillaceous than the next underlying beds, and tending to weather bluish gray. Top at traverse N8°W 246 feet. *Leperditia scalaris* abundant at several horizons. Seven feet above base: "*Spirifer*" *modestus plicatus* (c), *Leperditia scalaris* (a), *Zygobeyrichia barretti* (c). *Dizygopleura sp.* (c); 4 feet: "*Spirifer*" *modestus* (r), *Leperditia scalaris* (a), *Zygobeyrichia barretti* (a), *Kloedenia centralis* (a), *Dizygopleura* sp. (c), *Eukloedenna* sp. (r).	15	30
Thin-, irregularly bedded somewhat lumpy dense to finely crystalline impure limestone, the weathered surfaces greenish to yellowish. There are some thin irregular partings of calcareous greenish shale, especially 5 to 15 feet above base. Measured with ruler to east of traverse line, which turns at 195 feet and runs N8°W to 246 feet. Reeside reports *Stenochisma lamellata*, "*Spirifer*" *vanuxemi* (probably *modestus plicatus*), *Rhynchospira globosa*, *Leperditia* sp.	15	15
TONOLOWAY LIMESTONE:		
Dense drab blue limestone, medium-bedded at top and bottom, thin-bedded to platy at middle. Not lumpy. Traverse N33°E to 195 feet. N76°, 37½°NW.	3	103
Thinly laminated limestone, weathering platy, dove-gray to yellowish. N33°E to 188 feet.	7	100
Thin-bedded dense dark blue limestone, in part thinly laminated. Traverse N33°E to 173 feet.	11	93
Concealed above. Some impure laminated limestone 117 to 127 feet traverse appears to dip southeast, but may have slumped. Traverse N33°E to 149 feet.	14(?)	82
Laminated dense dark blue limestone, mostly weathering platy. Base seen at entrance of old dirt road leading east from highway; higher beds are seen in small quarry pits just east of highway. Mostly concealed 8 to 31, 36 to 70, 83 to 117 feet traverse. Traverse N1°E to 117 feet. At 85 feet: N85°E, 36°NW.	68	68
Concealed to south.		

SECTION 8: NEAR WARREN POINT, FRANKLIN COUNTY, PENNSYLVANIA

Helderberg and Oriskany beds are finely exposed along Licking Creek, near Warren Point at the southwestern tip of Franklin County, Pennsylvania, in the area of the Hancock Quadrangle of the U. S. Geological Survey. The principal section is on the south side of the creek, where it bends southward across the Maryland line, and cuts across the northeastern end of Elbow Ridge. It is several hundred feet west of the bridge crossing the creek about 1 mile east of Warren Point and 1½ miles southwest of Yeakle Mill.

The Helderberg-Oriskany sections at this locality were studied and described by R. B. Rowe (Dissertation, Johns Hopkins University, 1900; 205; pp. 176-178, 188-190). The following lithologic description is taken largely from Rowe's work, with some modification by the writer. The faunal descriptions are by Schuchert, except as otherwise noted. The Coeymans age of the quartzitic sandstone at the base of the section was shown by C. K. Swartz (205; p. 178). The sandstone had been considered Oriskany in age by early workers, New Scotland by Rowe and Ulrich.

The section is of great interest because it shows the characters of the Helderberg beds in their most easterly belt of outcrop in this latitude. The area is isolated by folding and faulting from the more northerly and westerly outcrops in Pennsylvania and Maryland, as can be seen in Figure 7. The stratigraphic sequence is markedly different from that near Warfordsburg, only 7 miles to the northwest. The striking changes in this short distance include: (1) change of the Coeymans formation from a somewhat arenaceous limestone to a quartzitic sandstone; (2) appearance of a fossiliferous limestone, about 90 feet thick, and containing a late Helderbergian fauna. This limestone has been correlated with the Becraft limestone of New York by Rowe and subsequent workers. It is believed to be continuous southward with the "Becraft" limestone around Monterey and Clifton Forge, Virginia (F. M. Swartz, 207; pp. 42-44). The writer has pointed out that this limestone is largely younger than the Becraft limestone of New York, and is evidently in part equivalent to the *Dalmanites dentatus* zone which has been included in the Oriskany formation in New Jersey. The name Licking Creek limestone is here used for it, not so much because of this particular difference in age, but because it is doubtful whether the member was ever physically continuous with the type Becraft of New York.

DEVONIAN SYSTEM:

Feet
Unit Total

ORISKANY GROUP:

RIDGELEY SANDSTONE:

Cherty arenaceous limestone and calcareous sandstone, containing "*Spirifer*" *arenosus* fauna.

HELDERBERG GROUP:

LICKING CREEK LIMESTONE:

Light gray limestone free of chert. *Rhipidomella oblata?* (r), *Leptaena rhomboidalis* (r), *Schuchertella woolworthana* (aa), *Strophonella punctulifera* (r), *Eatonia medialis* (c), *E. singularis* (r), *E. peculiaris* (r), *Plethorhyncha camp-*

	Feet	
	Unit	Total
bellana (a), "*Spirifer*" *concinnus** (aa), "*S.*" *cyclopterus* (a), *Anoplotheca concava* (rr), *Meristella arcuata* (c), *Rensselaeria subglobosa* (aa), *Leptostrophia blainvilli* (a)	25	87
Light gray limestone, with numerous layers of black chert.	20	62
Thick-bedded light gray limestone with a few nodules and one or two layers of chert. 5 to 10 feet above base the writer collected *Rhipidomella oblata* var. *(R. assimilis?)* (c), *Leptaena rhomboidalis*, large (c), *Schuchertella woolworthana* (c), *Chonetes pustulocristata* (r), *Eatonia medialis* (c), *E. singularis* (c), "*Spirifer*" *cyclopterus* (a), "*S.*" *concinnus* (r), *Anoplotheca concava* (c), *Rensselaeria subglobosa* (r), *Leiopteria?* sp. (r). Schuchert reported "*Spirifer*" *concinnus* (a), *Plethorhyncha campbellana* (r).	25	42
Mostly black chert in irregular layers; some interbedded limestone near top.	17	17
MANDATA SHALE (?):		
Concealed. There is a marked bench at this horizon, and the beds are nowhere exposed. It is probable that much of this interval consists of shales like the next underlying beds, and that they have weathered back because they are less resistant than the adjacent cherty limestones.	35	39
Dark gray calcareous shale or very impure limestone, weathering buff, porous. Upper half very fossiliferous, containing *Octonaria thlipsurelloides* zone: *Pholidops ovata* (aa), *Rhipidomella oblata*. (c), *Leptostrophia planisulcata* n. sp. (a), *L. beckii* (c), *Strophonella geniculata* (r), *Schuchertella woolworthana* (r), *Eatonia singularis* (r), "*Spirifer*" *cyclopterus* (a), "*S.*" *concinnus* (?) (r), *Rensselaeria* sp. (r), *Bollia schmidtella* sp. (r), *Bollia cristata* and vars. (c), *Parazygocornis*, node weak (r), *Pyxiprimilia* n. sp. (rr), *Octonaria thlipsurelloides* (a), *Thlipsura robusta* var. (a), *Thlipsurella* n. sp. (c), *Cavellina* sp. (c), *Tubulibairdia tubulifera* (c).	4	4
NEW SCOTLAND LIMESTONE:		
Thick-bedded light gray limestone with much interbedded chert tending to weather whitish. *Eospirifer macropleurus* (a) throughout, together with *Leptaena rhomboidalis*, *Strophonella punctulifera*, *Meristella arcuata*.	11	28
Thick-bedded gray limestone. Near the base the writer collected *Isorthis perelegans* (a), *Leptaena rhomboidalis* (c), *Leptostrophia planulata?* (c), *Schuchertella woolworthana* (c), near top, *Eospirifer macropleurus* (c).	7	7
COEYMANS LIMESTONE:		
Elbow Ridge sandstone member: Thick-bedded quartzitic sandstone, some crinoid stems; *Rhipidomella oblata* (r) near top. On a road crossing the crest of Elbow Ridge just south of the Maryland line, C. K. Swartz collected (1913: 178): *Favosites helderbergiae*, *Pleurodictyum lenticulare*, *Rhipidomella oblata*, *Leptaena rhomboidalis*, *Strophonella punctulifera*, *Gypidula coeymanensis* (a).	10	10
Concealed to west. The thickness of the Keyser in this outcrop belt has not been determined.		

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* Mostly "*S.*" *aroostookensis*, see plate.

SECTION 3: NEAR AUBURN, SCHUYLKILL COUNTY, PENNSYLVANIA

Keyser, Helderberg, and associated beds are absent at the following section, along the country road on the east side of the Schuylkill one mile southeast of Auburn, Schuylkill County, Pennsylvania, in the area of the Pottsville Quadrangle of the U. S. Geological Survey. The section was measured by C. K. Swartz and F. M. Swartz.

The writer believes that absence of the Keyser and Helderberg beds at this locality, and probably westward toward the eastern tip of Perry County, is due to unconformity; the structure may also be complicated at places by faults. The stratigraphic relations leading to this conclusion are discussed elsewhere.

	Feet	
	Unit	Total
DEVONIAN SYSTEM:		
MIDDLE DEVONIAN SHALE:		
Black shale. *Styliolina fissurella.*		
Concealed.		
ONONDAGA LIMESTONE:		
Fossiliferous limestone. *Athyris spiriferoides*, etc.	18	26
Concealed.	8	8
ORISKANY (PALMERTON?) SANDSTONE:		
Thick-bedded conglomeratic sandstone. Pebbles commonly ⅛, rarely ½ inch in diameter.	3	3
SILURIAN SYSTEM:		
BLOOMSBURG RED BEDS:		
Alternating red and green sandstone and shale. 27 feet at top; red sandstone and shale, very thick, below.		

SECTION 2: ON NORTH SIDE OF BRODHEAD CREEK, MONROE COUNTY, PENNSYLVANIA

Helderberg and Oriskany beds are well exposed along the tracks of the Erie (New York, Susquehanna and Western) Railroad, on the north side of Brodhead Creek, just east of Minisink Mills, about 1 mile north of Delaware Water Gap village, and 2 miles east of East Stroudsburg, Monroe County, Pennsylvania. The section is at the northern edge of the Delaware Water Gap quadrangle of the U. S. Geological Survey, opposite the highway bridge leading east over Brodhead Creek toward Shawnee-on-Delaware.

This section was described by I. C. White in 1882 (228; pp. 239, 240) under the name Experiment Mills section. It was also described by the writer in 1929 (208) from notes based on a trip to the locality with students in 1926. The strata between the sandstone beds of the Oriskany, and the Stormville conglomerate member of the Coeymans, were included by White in his "Stormville shale." The writer in 1929 pointed out that this shale is a composite unit, apparently including equivalents of the New Scotland, Becraft, and Port Ewen as seen farther north. This view has proved to be correct, except that the upper 60 feet of the "Stormville shale" as described in 1929 are now believed to be Oriskany in age.

Bearings are magnetic, the traverse beginning at the west abutment of the railroad bridge over the highway to Shawnee-on-Delaware.

	Feet	
	Unit	Total
DEVONIAN SYSTEM:		
ORISKANY GROUP:		
Thick-bedded siliceous limestone, black chert, and coarse-grained sandstone, 55 feet, above; thick-bedded siliceous shale, 60 feet, below, with lenses of dark chert, weathering rusty, in lower 2 feet. Near base: N60°E, 74°NW.		
HELDERBERG GROUP:		
PORT EWEN SHALE:		
Dark gray somewhat siliceous shale, weathering ashy to brownish gray. These beds are slightly less resistant than the overlying strata. Traverse N46°W to 666 feet. Lenses of impure limestone 1 foot below top contain *Rhipidomella musculosa* (rr), *Chonetes aroostookensis* (a), *C. pustulocristata* (a), *Eatonia medialis* (c), *E. singularis* (c), "*Spirifer*" *concinnus* (c), somewhat more transverse, ribs a little stronger than typical, "*S.*" *murchisoni* (r), cf. *Rensselaeria subglobosa* (r), *Pterinea?* sp. (c), *Homalonotus vanuxemi* (c), *Dalmanites* sp. (not *D. dentatus*) (a) *Phacops logani?* (c), *Paraschmidtella dorsopunctata* (c), *Aechmina* n. sp. (r), *Ulrichia affinis* (rr), *Bollia cristata* var. (r), *Kloedenia punctulopustulata* n. sp.* (r), *Thlipsura dawsi* n. sp. (a), *T.* 2 n. sp., near *T. robusta*, (aa). *Thlipsurella multipunctata* (aa), *T. lachrymosa* n. sp. (c), *Tubulibairdia tubulifera* (aa), *Cavellina paraquaesita*, (c). 12 to 13 feet below top: *Leptostrophia oriskania* var. (c), *Schuchertella woolworthana* var., small (aa), *Chonestes pustulosa* n. sp. (c), *Eatonia medialis* (c), "*Spirifer*" *cyclopterus* (c).	29	136
Concealed; some ash-gray shale with slaty cleavage 608 to 611 feet traverse. Traverse N46°W to 630 feet.	30	107
Dark gray somewhat calcareous shale, weathering ash-gray and rather soft, and splitting across the bedding into subslaty pieces. Dip about 50° to 55°NW. Traverse N46°W to 592 feet. Near top: *Platyorthis planoconvexa* (a), *Leptostrophia oriskania* var. (aa)), *Schuchertella woolworthana* var., small (c), "*Spirifer*" *concinnus* (c), in part with grooves on lateral ribs="*S.*" *aroostookensis* (r), *Cyrtina dalmani* (r) *Phacops* sp. (r), *Dalmanites* sp. (r), Near middle: *Platyorthis planoconvexa* (a), *Leptostrophia oriskania* var. (aa), *Schuchertella woolworthana* var. small (c) *Chonetes pustulosa*, (r), *Eatonia medialis* (r), small, "*Spirifer*" *cyclopterus*, ribs 8 to 9 (c), *Cyrtina dalmani* (r), *Dalmanites* sp. (r).	38	77
Mostly concealed; some calcareous shale, weathering ash-gray, and splitting across bedding, on bank in lower and upper parts. N46°W to 539 feet.	39	39
BECRAFT LIMESTONE (?):		
Hard dark gray impure limestone to siliceous calcareous shale, breaking across bedding, and tending to weather ash gray. Dip about 50°NW. Traverse N46°W to 485 feet. The age of these beds is very uncertain, and their reference to the Becraft is highly questionable.	14	14
NEW SCOTLAND SHALE AND LIMESTONE:		
Mostly concealed; some calcareous shale, splitting across bedding and weathering ash gray, 408 to 418, 432 to 436 feet traverse. Traverse N49°W to 465 feet.	43	76
Kalkberg limestone member: Thick-bedded dark gray siliceous and argillaceous limestone, tending to break across the bedding; with some layers of small nodules of dark chert,		

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* These new ostracoda will be described in a forthcoming paper.

	Feet	
	Unit	Total
and with zones of limestone nodules, up to 8 inches thick, and weathering light gray against the dark brownish surfaces of the matrix. Top dips to track level at 239 feet traverse. Concealed 11 to 17 feet above base. *Rhipidomella oblata*, *Eatonia medialis*, *Eospirifer macropleurus*. Near base: N53° E, 30° NW. Near top: 37° NW.	33	33
COEYMANS LIMESTONE:		
Stormville sandstone member: Thick-bedded hard arenaceous gray limestone, with lenticular beds of coarse sand and some small quartz pebbles, especially near the base. Sand laminae weather in relief on exposed surfaces. Concealed 6 to 9 feet above base. Top projected to track level at 341 feet traverse.	14	42
Very thick-bedded somewhat arenaceous bluish gray, finely and some coarsely crystalline limestone, breaking into rather irregular fragments. There are numerous 2- to 6-inch coquinites made up mostly of valves of *Gypidula coeymanensis*, especially in the lower 8 feet and 10 to 13 feet above base; the species occurs somewhat less abundantly at higher levels. There are persistent beds of dark chert 3 to 4 inches thick at 9 and 14 feet; some irregular nodules at 13 and 17 feet; and a prominent 6-inch chert bed at 24½ feet. Top dips to track level at 306 feet of traverse; base of exposed beds is at axis of anticline 156 feet traverse, the traverse beginning at the west abutment of the railroad bridge over the highway to Shawnee-on-Delaware.	28	28
Concealed below level of tracks. In a nearby section along the highway just south of Shawnee, the Coeymans is 79 feet thick, including very thick-bedded, somewhat arenaceous limestone, 63 feet, below; more arenaceous pebbly limestone or calcareous conglomeratic sandstone (Stormville member), 16 feet, above. 31 feet of Manlius limestone, and 8 feet of Rondout limestone are also exposed.		

SECTION 1: NEAR DECKERS FERRY, MONROE COUNTY, PENNSYLVANIA

The Keyser and Helderberg formations are in part well exposed in Monroe County near Deckers Ferry, at the Wallpack Bend of the Delaware River, about 2 miles east of Bushkill, Pennsylvania, in the area of the Wallpack Quadrangle of the U. S. Geological Survey. The section here described is seen at three distinct but nearby places, as follows: (1) the Bossardville and Decker are exposed near the point of the Helderberg-Oriskany ridge, locally known as the "Hogback", behind the house on the farm (1937) of P. H. Smith, near the old ferry landing. (2) The top of the Decker sandstone, the Rondout, Manlius, Coeymans, and parts of the higher beds are exposed along the dirt road leading over the north end of the Hogback to Bushkill. (3) The Manlius, Coeymans, New Scotland, and Becraft are more or less continuously exposed along the bank of the Delaware River, on the northwestern flank of the Hogback. The river section is an excellent place to observe the strata, and provides a fine collecting ground, especially for the New Scotland shales. Because of the small angle to the strike, the river section is not a very satisfactory place to measure the strata, and figures that are here given are based on direct measurement of the Bossardville and Decker beds near the point, and a traverse and some direct measurements along the road over the hogback. The traverse across the upper beds lies at a small angle to the strike, so that thicknesses are uncertain. Because of poor exposures, the position of the Helderberg-Oriskany boundary was not determined. All bearings are magnetic.

DEVONIAN SYSTEM:	Feet	
ORISKANY GROUP:	Unit	Total
Largely concealed crossing top of main ridge of hogback, *"Spirifer" murchisoni*, *Anoplotheca flabellites* in siliceous, cherty limestone on north side of road. Road follows summit of hogback for about 330 feet to 2761 feet traverse.		
Concealed along road. Traverse S57°W 265 feet, S67°W 375 feet, S60°W 150 feet, to 2431 feet total; rise 20 feet.		
HELDERBERG GROUP:		
PORT EWEN SHALE:		
Dark gray to black siliceous and somewhat calcareous shale, splitting across the bedding; partly concealed. S79°W 120 feet, S54°W 30 feet, total 1641 feet, rise 35 feet. A shoulder paralleling the main ridge intersects the road at about 1640 feet traverse, and this point is arbitrarily used as the top of the Port Ewen. Further work is needed to establish the Helderberg-Oriskany boundary in this area.	66	165
Concealed. Traverse S76°W 83 feet, total 1221 feet, rise 12 feet.	31	99
Dark gray to black siliceous, somewhat blocky shale, splitting across bedding. Weathers into small more or less hackly fragments, and becomes gray to brownish. S65°W 110 feet, total traverse 1138 feet, rise 11 feet.	32	68
Concealed. S52°W 35 feet, S65°W 110 feet, rise 11 feet.	36	36
BECRAFT LIMESTONE:		
Thick-bedded finely crystalline blue limestone. This limestone is also seen along the bank of the Delaware, where it occurs as large slumped masses. At base: *Levenea subcarinata* (aa), *Rhipidomella* sp. (r), *Eatonia singularis* (r), *Atrypina imbricata* (r), *"Spirifer" cyclopterus* (aa), *"S." perlamellosus* var. (a). *"S." concinnus* was not observed. Seen along road to opposite S52°W 200 feet, total 883 feet, rise 0 feet.	20	20
NEW SCOTLAND SHALE AND LIMESTONE:		
Concealed along road. Traverse S50°W 213 feet, total 683 feet, rise 13 feet.	35	79
Somewhat calcareous and siliceous shale, much fractured across bedding. These beds correspond roughly to highly fossiliferous shale seen along bank of Delaware River, north of and below the road. Fauna along river: *Rhipidomella oblata* (c), *Leptaena rhomboidalis* (c), *Leptostrophia beckii* (a), *Strophonella punctulifera* (c), *Schuchertella woolworthana*, small (aa), *Eatonia medialis* (c), *Eospirifer macropleurus* (a), *"Spirifer" perlamellosus* (c), *"S." cyclopterus* (c), *Trematospira multistriata* (r), *Anoplotheca concava* (c). Traverse S36° W, 132 feet traverse, total 470 feet, rise 13 feet.	6	44
Concealed along road. Traverse S65°W 68 feet, S36°W 98 feet, total 338 feet, rise 11 feet.	15	38
Kalkberg limestone member: Medium-bedded siliceous limestone, with some layers of chert, and with lenses of purer limestone, weathering light gray. In exposures along river: *Isorthis perelegans* (c), *Schuchertella woolworthana* (r), *Eospirifer macropleurus* (c), *Phacops logani* (r).	23	23

	Feet	
	Unit	Total
Coeymans Limestone:		
Concealed along road, the traverse S65°W 172 feet, rise 20 feet to top of Kalkberg member, side traverse N56°W 62 feet to base of exposed Kalkberg. Along river, the upper 8 to 10 feet of the Coeymans consists of calcareous sandstone and arenaceous limestone, with lenses of fine quartz pebbles (Stormville sandstone member).	25	75
Thick-bedded coarsely crystalline gray crinoidal limestone; upper beds exposed along road at a sharp S-shaped bend; lower 30 to 35 feet make a sharp hogback northeast of road, *Gypidula coeymanensis* (c) 1 foot above base and at higher horizons.	50	50

SILURIAN SYSTEM:

KEYSER LIMESTONE:

Manlius Limestone Member:		
Mostly thick-bedded, dense to finely crystalline dark blue limestone. Top is not well defined; as here drawn, the upper 2 feet of the Manlius include lenses of more coarsely crystalline limestone, in part with heads of small tubed *Favosites*. *Stropheodonta varistriata* (aa) 4 to 6 feet below top: "*Spirifer*" *vanuxemi* (a) near middle, *Tentaculites gyracanthus* (c) 6 to 10 feet above base.	33	121
Rondout Limestone Member:		
Concealed. (Rondout?).	6	88
Thick-bedded dense magnesian limestone, weathering buff; = peth stone bed of Cooke.	7	82
Medium to thick-bedded dense to finely crystalline limestone. Some stromatoporoides 3 to 4½ feet above base. *Leperditia* sp. (aa), especially in upper 2 feet.	8	75
Concealed. (Rondout?).	5	67
Decker Sandstone Member:		
Medium-bedded hard, mostly fine-grained calcareous, somewhat conglomeratic sandstone. Three feet of sandstone, apparently top of these beds, seen along road; but descriptions of these and lower beds are taken from exposures near end of point, near old ferry landing.	8	62
Concealed.	17	54
Concealed below; at top about 10 feet of thin-bedded fine grained calcareous sandstone, varying to arenaceous limestone. *Chonetes jerseyensis* fauna.	20	37
Medium-bedded gray arenaceous limestone to calcareous sandstone. *Chonetes jerseyensis* fauna.	6	17
Concealed.	8	11
Medium-bedded somewhat arenaceous bluish limestone. *Chonetes jerseyensis* fauna.	3	3
Bossardville Limestone:		
Dense laminated limestone, partly concealed.	22	22
Concealed.		

Footnote for page 48. In listing Devonian genera of the Keyser in 1929, the writer of course drew from the extensive investigations in Maryland and Pennsylvania, as well as from work in the Virginias. *Actinopteria* and *Aviculopecten* were cited from Maryland identifications; their value is, perhaps, questionable. *Beachia* (*B. proavita* Schuchert) has been reported in Maryland and more widely in central Pennsylvania. *Rensselaeria, Merista,* and *Meristella* are represented by specially significant species, generally persistent in Maryland, central Pennsylvania, and the Virginias. *Chonostrophia* does not belong in this category, as it is not known in the Keyser. Reduction of the Devonian and Helderbergian elements in the faunas of the Keyser equivalents in New Jersey and New York represents a restriction of those faunas which lessens their value as a guide to the age and classification of the Keyser and its correlates.

CHAPTER III

THE ORISKANY GROUP

By Arthur B. Cleaves

INTRODUCTION

The Oriskany sandstone for the past century has been one of the best known stratigraphic units in the Devonian of eastern North America. Not only are its lithology and faunas distinctive, but remarkable also is the ubiquitous nature of it and its correlates in its area of outcrop from northeastern Canada and New England to Alabama and southeastern Missouri.

Interest in the Oriskany of Pennsylvania and New York has recently assumed new importance because of the discovery of the Oriskany sand as a source of natural gas. Prior to this the chief commercial value of the sandstone came from its locally splendid qualifications as a high grade glass sand.

The writer spent two years in the study of the Oriskany group throughout Pennsylvania and portions of adjoining States. In this report a particular effort will be made to avoid encroachment upon the studies of Frank M. Swartz, who, prior to and at the same time, occasionally in the field with the writer, has worked on the formations of the Helderberg group underlying the Oriskany. Dr. Swartz's extensive studies of the Helderberg group (see Chapter II), including its lithologic and faunal relationships to the Oriskany, entitle him to priority in discussing the detailed aspects of those relationships.

ACKNOWLEDGMENTS

The writer is indebted to Dr. Frank M. Swartz for his assistance in the field and in discussions relative to the problem. Dr. Bradford Willard has spent several days examining sections in the field with the writer and has been kind enough to criticize the manuscript. Mr. William Scheibley of Landisburg, Perry County, presented his splendid Oriskany collection, and Frank E. Tressler, Esq., of New Bloomfield, in the same county, has collected with me in the field on several occasions and has added many splendid specimens to the Survey's collection.

PREVIOUS WORK AND SYNOPSIS OF STATUS OF PROBLEM

The presence of what is now known as the Oriskany was first recorded in Pennsylvania by Henry D. Rogers in 1836 (171). He elaborated on these strata in 1838 (172) and in reports appearing in later years (particularly 177). In his first report he recognized only the sandstone that we now call Ridgeley, but in later accounts he established underlying cherts, now in part the Shriver, as being associated with the sandstone. Rogers did not designate the Oriskany by any geographic name; if he had done this it is quite likely that the Oriskany would have borne a name from Pennsylvania because his first two reports antedated Vanuxem's naming of the formation in New York (216).

Much has been written about the Oriskany in Pennsylvania in the works of the Second Geological Survey of the State by such geologists as I. C. White (228, 229, 230), E. W. Claypole (72) and J. J. Stevenson (198). References to and comments upon their work will appear later.

More recent publications dealing directly or indirectly with the Oriskany have been published by C. R. Fettke (88) on Glass Manufacture and the Glass Sand Industry of Pennsylvania, Butts and Moore (25) on the Geology of the Bellefonte Quadrangle, Stow (203) on Conditions of Sedimentation and Sources of the Oriskany Sandstone as indicated by Petrology, F. M. Swartz in his Helderberg publications (207, 208) and his report on Lower Devonian ostracoda in Pennsylvania (209, 211), the writer in his Oriskany Thicknesses in Pennsylvania (75) and other authors in reports on subsurface geology in the gas and oil fields of Pennsylvania.

New York: The name Oriskany originated in New York State where Amos Eaton called it first the "*Shell Grit*"; the New York Geological Survey later referred to it as the "*White Sandstone*" or the "*Grey Brachiopodous Sandstone*"; but it remained for Vanuxem in 1839 (216) to name it the Oriskany from a section at Oriskany Falls where it is a very pure white quartz sandstone approximately 20 feet thick. John M. Clarke called its fossils the "*Hipparionyx* fauna."

The original Oriskany applied to the sandstones containing the "*Spirifer*" *arenosus-Hipparionyx proximus* fauna west of Schoharie County, in central and western New York. Today a calcareous facies of the Oriskany in New York is known. In the region of the Hudson Valley the Oriskany loses its typical appearance, becoming a chert and cherty or siliceous limestone. Thickening occurs. The upper Oriskany is displaced by very fossiliferous limestone, and in part of the area a basal conglomerate is present. In Ulster County the name Glenerie limestone was assigned to the limestone beds and the Connelly conglomerate to the basal conglomerate (43). In Orange County Shimer (192) divided the Oriskany into lower and upper units. The lower, 30 feet thick, is known as the "*Dalmanites dentatus* zone" and contains intermingled Helderberg and Oriskany species; the upper 150 feet thick, is called the "*Spirifer*" *murchisoni* zone. The *Dalmanites dentatus* zone has been called the "Port Jervis limestone" by Chadwick (43).

New Jersey: In northwestern New Jersey the Oriskany is about 170 feet thick and consists largely of siliceous limestones. The upper beds in Wallpack Ridge in the southern part of the area of outcrop are displaced by calcareous sandstone. The Oriskany in New Jersey has been best described by Weller (223). He recognized three distinct faunal zones. From the top to the bottom these are: the "*Spirifer*" *murchisoni* zone, the *Orbiculoidea jervensis* zone, and the *Dalmanites dentatus* zone. He recognized strong Helderberg characteristics in the fauna of the *Dalmanites dentatus* zone and hesitatingly placed it in the Oriskany. There exists today in the minds of some stratigraphers a question concerning the Oriskany assignment of this zone.

New England and Canada: In New England beds of Oriskany age are known in Maine and New Hampshire. In Maine the Oriskany is represented by the Moose River sandstone (64, 264), and in New Hampshire by the middle portion, at least, of the Littleton formation (15). The Moose River sandstone consists of sandstones, conglomerates, and arenaceous shales and is reputed to have a thickness of 2,880 feet. The Littleton formation in New Hampshire is strongly metamorphosed but in the low grade zone of metamorphism the identifiable fossils occur in slate and slaty sandstone. The formation has a thickness probably in excess of 3,000 feet. Whereas the identified specimens come 2,500 feet above the base, there are poorly preserved brachiopods from both the base and the top which may signify the Oriskany age of the entire formation. In Quebec, in the Gaspé Peninsula the Oriskany fauna occurs in the divisions 7 and 8 of the Grande Grève limestone. These strata are a pure blue-gray limestone free from chert (64).

Maryland: The Oriskany of Maryland is divided into two units, the upper Ridgeley sandstone member and the lower Shriver chert member. The division is based on both lithologic and faunal differences (143). The work in Maryland first established Oriskany divisions that have been found to be applicable, in part at least, in Virginia, West Virginia and Pennsylvania.

West Virginia: In West Virginia Oriskany strata are similar to the beds in Maryland, and the names Ridgeley, for the upper sandy beds, and Shriver for the lower cherty beds, are in good standing. In addition a dark chert unit lying above the Ridgeley sandstone and below the Marcellus black shale, in the stratigraphic position of the Onondaga, but containing an Oriskany fauna, is called the Huntersville chert (2, 159, 160).

Virginia: The Oriskany in Virginia is a calcareous sandstone, ranging in thickness from a few feet to 150 feet. It is generally of uniform character, abundantly fossiliferous at some horizons, and because it corresponds, faunally and lithologically to the Ridgeley sandstone it is correlated with that formation in Maryland and West Virginia (24). The problem of the Shriver (the lower formation of the Oriskany group in Maryland and West Virginia) in Virginia has not, to date, been fully solved. F. M. Swartz (207) says:

> In Virginia, however, a cherty limestone with a Becraft fauna is found above the New Scotland at Clifton Forge, Healing Springs, Bells Valley, and some neighboring localities. A tongue from the upper part of this limestone is present at Warm Springs and Monterey above bedded impure chert of Shriver rather than Becraft type, although they contain less mud than is typical in Maryland. The demonstration of the Shriver age of these chert beds is difficult because they, like the typical Shriver, contain so few fossils. They do however, seem to be continuous with the Shriver chert of Maryland, as shown by intervening sections. Stratigraphic con-

siderations, therefore suggest that the Shriver chert and the Becraft limestone (at least the Becraft of Maryland and Virginia) are essentially equivalent in age, the faunas being different because of differences in habitat conditions.

Hence, the Shriver of Virginia being below the Becraft can hardly be Oriskany.

Alabama: In Alabama the Oriskany is definitely present. The Jemison chert in Chilton County is probably Oriskany, and, according to Butts (23), may be a correlate of the Huntersville chert in West Virginia. It is possible that the Yellow Leaf quartz schist overlying the Jemison chert may be Oriskany also, although no fossils have been found in it to date. Some sandstones in Alabama included in the Frog Mountain sandstone are definitely Oriskany although the typical Frog Mountain sandstone is Onondaga (23) and other Frog Mountain sandstones are probably of Marcellus and Hamilton ages. According to Butts, ''except for the occurrence of a small thickness of Oriskany in the region southwest of Bessemer and southwest of Vance, in Tuscaloosa County, no Oriskany is known in Alabama.''

Georgia: In northwest Georgia the Armuchee chert, which underlies the Frog Mountain sandstone, in the Rome Quadrangle, contains a clearly defined Oriskany fauna (193). The Frog Mountain sandstone was mapped by Hayes in the Armuchee chert, but later work by Butts indicates the superior position of the Frog Mountain sandstone.

Mississippi Valley: The Oriskany in the Mississippi Valley is found in western Tennessee, southeastern Missouri, and southwestern Illinois.

Tennessee: C. O. Dunbar, in 1919 (83), discovered new Oriskany strata in the Tennessee River valley. Prior to his discovery, and that of Weller (224) (briefly announced) in Missouri in 1913 the only known Oriskany strata in the Mississippi Valley were the Camden chert of Tennessee and the Clear Creek chert of Illinois. Dunbar attempted to prove that the Camden chert and the Clear Creek chert were not Oriskany, but Onondaga. However, because of recent work on the Camden chert by Cooper (personal communication) it is questionable whether he proved his case. The new Oriskany formations discovered by Dunbar are the Quall limestone and the Harriman novaculite. These are separated from each other by an erosional unconformity which must have been of short duration, for the faunas of each indicate younger Oriskany, the equivalent of the Ridgeley sandstone in Pennsylvania and Maryland.

Missouri: In 1928 Stuart Weller and Stuart St. Clair described the Little Saline limestone and its fauna in Ste. Genevieve County, southeastern Missouri (224). This fauna and formation, similar to the Quall and Harriman formations in Tennessee, is correlated with the upper Oriskany of New York and the Ridgeley sandstone of Pennsylvania and Maryland.

DISTRIBUTION

The Oriskany group in Pennsylvania includes all stratigraphic units between the overlying Onondaga group (including the Esopus shale in eastern Pennsylvania) and the underlying Helderberg formations. It is faunally distinct although possessing Helderbergian affinities. Lithologically it is distinct over most of the State, although in certain areas the lower beds merge with the upper Helderberg and can be separated only on the basis of faunal identities.

The group usually consists of two facies, sandstone above, and siliceous limestone below. The latter frequently varies, being displaced by shale and chert and often containing beds of only local significance. In central and south-central Pennsylvania the Oriskany is divided into two distinct formations, but in the eastern part of the State no division is permissable. The upper sandstone and related beds are called the Ridgeley formation and persist, with local unconformities, over the entire area of outcrop. The lower siliceous limestones, shales and cherts, identified as the Shriver formation, carry through from Maryland into south-central and central Pennsylvania. The Shriver loses its identity in Perry County and cannot be established in the eastern counties.

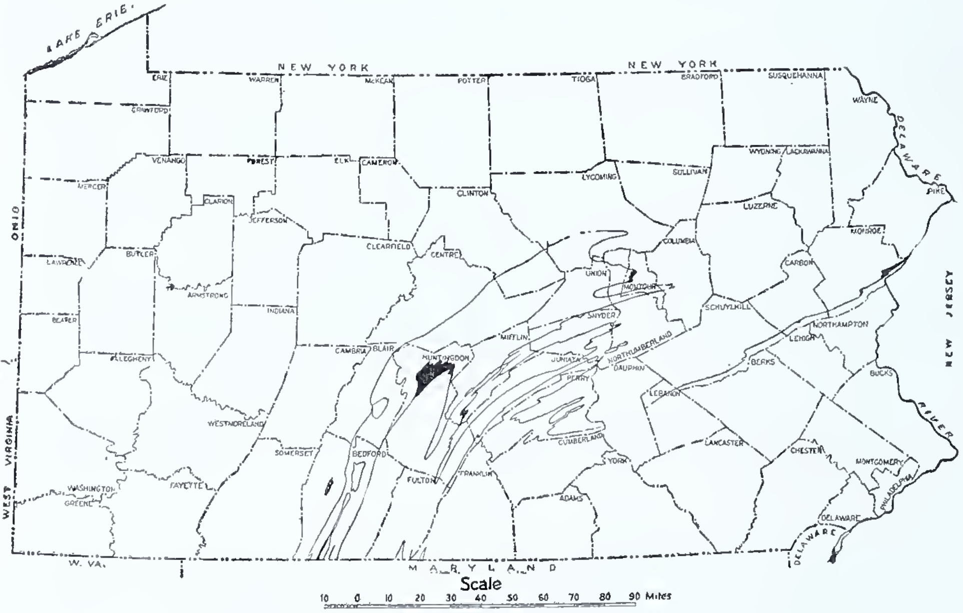

Figure 18. **Sketch map showing distribution of Oriskany group in Pennsylvania.**

Figure 18 shows the distribution of the Oriskany in the State. In Fulton County the line of outcrop is broken by faulting. In Lycoming County, between Jersey Shore and Williamsport, it is concealed but relatively thick sections at both ends of the concealed interval support the belief that the strata are present but buried beneath alluvium in the Susquehanna River flood-plain and glacial outwash. The Oriskany is present in eastern Montour County but cannot be traced into

Columbia County although its presence is suspected. It disappears in southeastern Perry County, cut out by a fault or by an unconformity, and does not reappear until western Schuylkill is reached. It passes out of Pennsylvania in eastern Monroe County at the Wallpack bend of the Delaware River.

LITHOLOGY

The Oriskany group, as already indicated, consists of the Ridgeley sandstone above and the Shriver siliceous limestone, shale and chert below. The former carries across the State along the line of the Oriskany outcrop but the latter does not occur in Franklin County or in, and east of, Perry County. Lithologic units in parts of Perry and in Schuylkill, Carbon and Monroe counties formerly thought to be Shriver, must now be considered members of the Ridgeley. In particular areas the Ridgeley and Shriver formations intergrade lithologically, but the faunas of each permit the establishing of their formational boundary.

TABLE XV. DIVISIONS OF THE ORISKANY GROUP

Central Pennsylvania	Eastern Pennsylvania
1. *Ridgeley formation:* sandstone, conglomerate, and occasional beds of chert.	1. *Ridgeley formation:* (a) Calcareous sandstone, argillaceous sandstone, and chert. (b) Arenaceous, siliceous, and calcareous shale. In part the Stormville shale,* of I. C. White.
2. *Shriver formation:* siliceous limestone, shale and chert. Includes in part the Stormville shale* of I. C. White, and the "White cherts"* of Claypole.	

Ridgeley formation

The name Ridgeley for part of the Oriskany sandstone was first used by the Maryland Geological Survey in its volume on the Lower Devonian deposits of Maryland, published in 1913 (143). The sandstone is named from Ridgeley, West Virginia, where it is splendidly exposed. Because of the similarity and continuity of these strata into Pennsylvania, the southern term is believed to be satisfactory and entirely appropriate in this State.

The Ridgeley sandstone in Pennsylvania is variable. In certain areas it is a calcareous sandstone which sometimes grades both vertically and laterally into an arenaceous limestone. In other areas it is a white quartz sandstone, or a bluish quartz sandstone locally metamorphosed into a quartzite. Conglomeratic beds occur at various horizons over much of its area of outcrop. The calcareous sandstones occur along the line of exposure in the region of the Allegheny Front from Lycoming County on the north to Bedford County on the southwest, in Fulton and Franklin counties to the south, and in Monroe County in the east where the Oriskany beds pass out of Pennsylvania into New Jersey.

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* Name discarded.

The *Stormville shale* of I. C. White (228) as originally defined in eastern Monroe County included "a series of ashen gray sandy and calcareous shales, about 150′ in thickness" lying directly beneath the "Oriskany pebble bed" and above a "calcareous pebbly conglomerate 10′-15′ thick" which he called the *Stormville conglomerate*. These shales are now definitely known to be in part Oriskany and in part Helderberg, hence the further usage of *Stormville shale* is inadmissable. (See Chapter II.)

In the Juniata-Susquehanna valleys region the Ridgeley is a noncalcareous sandstone, locally quartzitic. The cementing material consists of both primary and secondary silica (88).

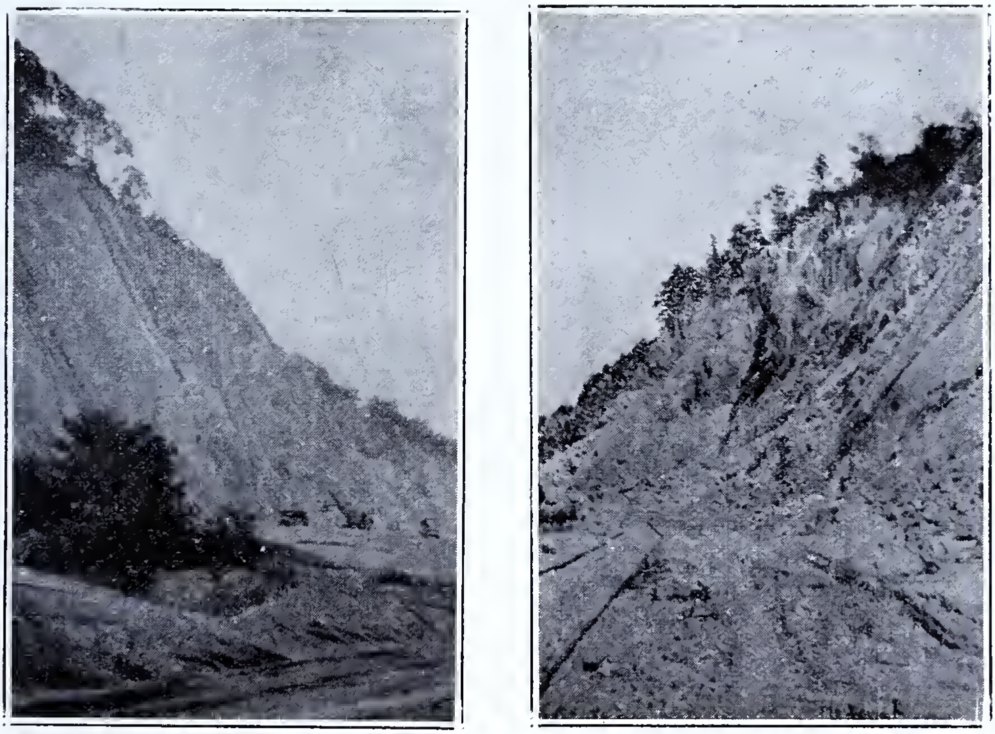
Where the Ridgeley is calcareous the fresh rock is bluish-gray and very tough. Weathering removes the calcareous cement, reducing the rock to loose blocks and sand. Locally, in Bedford County, pockets or pits have weathered out where the calcareous content of the rock has been especially high. These pits are often the source of exceptionally fine, silicified fossils, which, along with the sandy impurities in the original rock, have accumulated on the floors of the cavities.

In the region of the Juniata-Susquehanna valleys, where the noncalcareous Ridgeley outcrops, the strata are prone to find topographic expression in the form of ridges and pulpit rocks. On the other hand, in the same area the sandstone may be completely disintegrated and have no topographic relief. Fettke (88) concluded that certain factors govern the breaking down of the Ridgeley into loose sand: 1. The relative position of the outcrop with respect to the topographic features of the vicinity; and 2. The amount of fracturing the rock has undergone. In both cases the movement of ground and surface water across and through the sandstone, the depth of the bedrock below the level of the ground, the spacing and character of the joints, the amount of both ground and surface water, the amount of organic acids in the water, and other factors control the size and nature of the sand deposits, as well as the topographic expression of this formation.

The sand grains in the Ridgeley are predominantly quartz. In the Juniata-Susquehanna valleys Fettke reports that the Oriskany glass sands contain only limonite as a deleterious impurity and that is far from universally present. Analyses by Stow (203) of the Ridgeley of this area show 0.2 to .05 percent of heavy minerals present, and these include the constantly occurring suite, tourmaline, zircon, rutile and leucoxene. These plus the quartz are "definite evidence of derivation from pre-existing sedimentary rocks." The individual sand grains are generally subangular to angular, although in some districts, especially central Perry County, they are well rounded.

Conglomerates in the Ridgeley vary in their position. In some localities the entire Ridgeley may be said to be conglomeratic, in others the conglomeratic beds are mere pebble bands. The glass sand quarries near Mapleton in Huntingdon County show conglomeratic beds at several horizons in the sandstone, and one bed is known to occupy a zone 34 feet thick. In Carbon County, at Little Gap, where the Ridgeley is 25 feet thick, the conglomeratic beds occupy 12 feet of the stratigraphic section, underlain and overlain by medium-grained sandstone.

The conglomeratic beds are composed primarily of subangular to well-rounded white quartz pebbles. Frequently these pebbles, as in parts of Perry, Carbon, Huntingdon and other counties, are frosted, suggesting sorting of material by wind action prior to deposition and further sorting by wave and current action on the shores of the Oriskany seaway. In Monroe County where the Ridgeley is exposed on Godfrey Ridge, west of Brodhead Creek, black chert pebbles are common. The derivation of these chert pebbles from chert beds in the Helderberg seems probable and supports the theory of local unconformity separating the Oriskany from the Helderberg. The size of the pebbles, chiefly quartz, in the conglomeratic beds varies and in a sense must be considered relative to the grain size of the main body of sandstones in the series in which the conglomeratic beds occur. Coarse material 1/16 inch in diameter, occasionally 1/8 inch, may constitue a conglomeratic bed in one area, whereas, in another area such a bed may have pebbles averaging 1/8 inch to 1/4 inch, with occasional pebbles 1/2 inch in diameter. Rarely are pebbles in the Ridgeley more than 1/2 inch in diameter. The non-arenaceous beds in the Ridgeley occur chiefly in Carbon and Monroe counties, if one excepts the cherts that occur in the Ridgeley throughout the line of outcrop in many sections across the State.



Photographs by A. B. Cleaves

A B

Figure 19. **Mapleton quarries, Huntingdon County. *A,* Ridgeley sandstone in Columbia quarry looking south. The purity of the Ridgeley sandstone in this area makes it a high-grade glass sand. *B,* similar to *A,* taken in Empire quarry.**

The best section of Lower Devonian strata in Monroe County is on the east bank of Brodhead Creek, in the cut of the Erie (New York, Susquehanna & Western) Railroad between North Water Gap and Minisink Mills. In this section the writer places 120 feet of strata in the Oriskany. The upper 55-60 feet contain calcareous sandstone beds, the thickest 5 feet, and interbeds of black chert, chert nodules and siliceous limestone. Underlying the above beds are 60 feet of interbedded dark gray arenaceous shale, siliceous shale, and black chert beds. All the above strata are assigned to the Ridgeley, although the fossils in the lower beds are difficult to identify. However, the strata immediately underlying contain a good New Scotland fauna. The white cherts and clays of this county (153, 134), (sometimes thought to be Oriskany), are now known, because of their profuse New Scotland fauna, to be of Helderbergian age.

In Carbon County (Little Gap) approximately 25 feet of bluish-black, argillaceous, bedded sandstone underlies the known Ridgeley. This is probably Oriskany although no fossils have been found to substantiate the interpretation. Interbedded cherts in the Ridgeley are common in the east. In the region of greatest sandstone thicknesses the cherts associated with siliceous limestone usually occur near the base of the formation, as beds or nodules, where the Ridgeley and Shriver merge. Generally the cherts are black, but in some areas they are white, as the "White Cherts" of Claypole in Perry County. In some sections the Ridgeley sandstone is absent, being displaced by chert and siliceous limestone but identifiable by means of the "*Spirifer*" *arenosus* fauna.

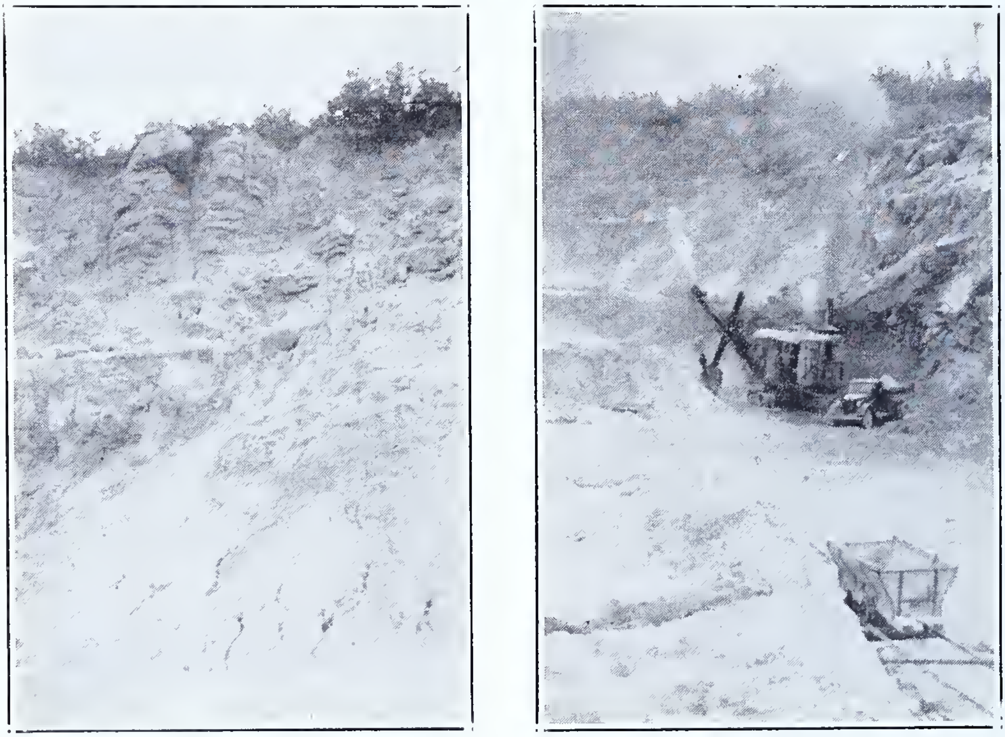

Photographs by A. B. Cleaves

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Figure 20. **Alexander Fire Clay Co. quarry, two to two and a half miles northwest of Huntingdon, Huntingdon County. *A*, Shriver overlain by Ridgeley. *B*, residual white clay, highly fossiliferous, in Shriver.**

Shriver formation

The Shriver was named by the Maryland Geological Survey from Shriver Ridge at Cumberland, Maryland (143, 205), where "it consists of a dark siliceous shale containing large quantities of black impure chert in the form of nodules or layers of nodules. Upon weathering, both shale and chert become buff or yellowish in color and break into sandy fragments, the chert in some cases becoming spongy."

In Pennsylvania the Shriver formation consists of impure siliceous limestone, impure black chert in beds, nodules, layers of nodules, and interbedded dark gray to black shale. Weathering frequently reduces the material to punky, buff to yellow fragments which, in part, remain in fairly thick blocks. The purer chert weathers white, and is often found in small pieces covering fairly extensive areas of ground.

Residual white clay occurs in the Shriver and is restricted to Huntingdon County. It is found in the Alexandria-Petersburg area, 2 to 2½ miles northwest of Huntingdon. The best exposure is in the open pit of the Alexandria Fire Clay Company, 3 miles southeast of Alexandria on the old Philadelphia Pike. Here, the Oriskany beds in Warrior Ridge are almost horizontal, with approximately 30 feet of Ridgeley sandstone capping the Shriver. The latter consists of white chert frequently nodular, white plastic clay, which is bluish-gray when wet, and alabaster-white, dry, and punky, buff-colored shale.

The good clay, 20 to 28 feet below the Ridgeley, does not extend through the pit in beds parallel to the overlying sandstone, but terminates abruptly in its lateral extent. This is thought to be caused by local slumping and slipping of the clay when saturated. The large number of sink-holes in the immediate vicinity suggest slumping caused by the removal of underlying Helderberg limestone. Leighton (134) believes that the clay has been derived from weathering of the upper chert and shaly beds in the Shriver. Additional silica may have been added by derivation secondarily from the overlying Ridgeley. The white clays in Monroe County, once thought to be Oriskany, are now assigned to the New Scotland. The fauna obtained from the associated cherts and the clay is characteristic New Scotland.

THICKNESS*

The Allegheny Front. At Hyndman, southeast of the Allegheny Front in Bedford County, the Ridgeley is a hard, tough, calcareous sandstone. The upper contact was not seen, and the upper portion of the section is complicated by folding and faulting, nevertheless there is a minimum thickness of 140 feet of Ridgeley sandstone. It weathers to a dirty brown loose sand, highly fossiliferous and contains local thin conglomeratic beds. The lower beds of the Ridgeley become a siliceous limestone, and contain chert nodules. Lithologically, the lower Ridgeley grades into the Shriver, but can be separated from it by the contained fauna. The Shriver formation here is an impure gray to black siliceous limestone and shale. Black chert beds one to four inches thick and black chert nodules are common in the upper two-thirds of the formation. It is 137 feet thick and is underlain by 24 feet of sparsely fossiliferous, black, slightly calcareous shale. The basal beds are fissile. This black shale is gradational into the Shriver, but the latter is more siliceous and breaks into rough blocks instead of shaly slabs. This underlying shale is commonly found at this level and is assigned to the New Scotland formation of the Helderberg group.

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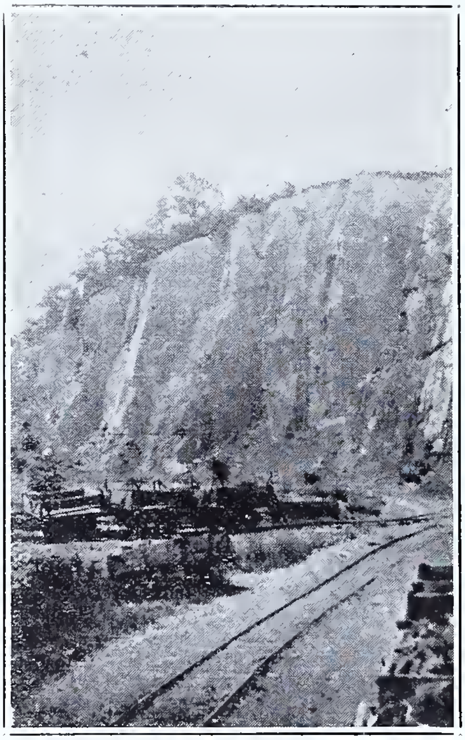
* This material is largely taken from the writer's paper, Oriskany thicknesses in Pennsylvania (75).

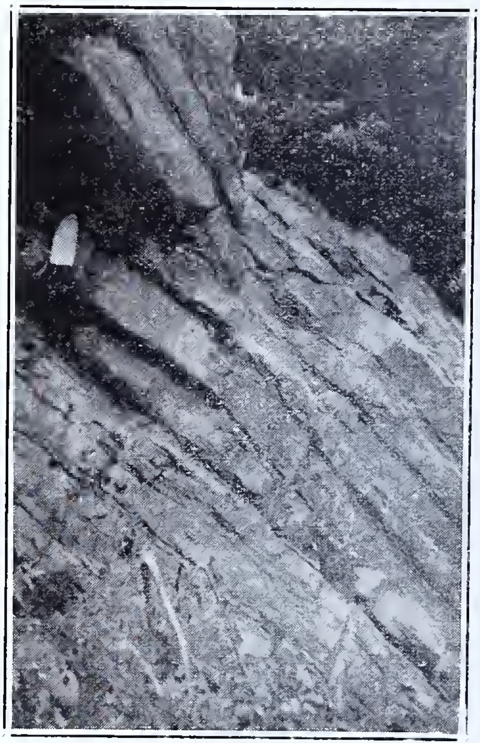
Five miles southeast, across Wills Mountain and Shriver Ridge at the Cumberland City Reservoir, 155 feet of Ridgeley and the upper 49 feet of Shriver are exposed at the Thomas W. Koon dam.

Nineteen miles northeast of the Cumberland City Reservoir near Bedford Springs an incomplete section contains 105 feet of Ridgeley, a total Shriver thickness of 40 feet, and 44½ feet of the New Scotland black shale member.



Photograph by A. B. Cleaves

Figure 21. **Oriskany exposed in quarry at Hyndman, Bedford County. The Ridgeley-Shriver contact is in the left background; basal Ridgeley, strongly calcareous, grades into the Shriver.**



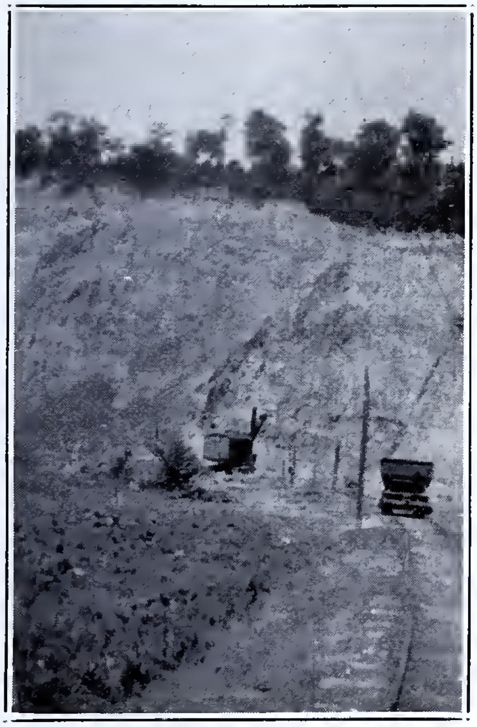
Photograph by A. B. Cleaves

Figure 22. **Oriskany exposure about one mile northeast of Hollidaysburg, Blair County. Ridgeley-Shriver contact is indicated by the bag. The lower Ridgeley is strongly calcareous and merges at the base with the Shriver.**

In Blair County, 30 miles north of Bedford Springs, in the vicinity of Hollidaysburg, composite sections indicate an approximate thickness of 110 feet of the Ridgeley. The upper beds have lost the calcareous cement and do not form the conspicuous ridges so common in other parts of the State. The lower beds are highly calcareous and merge at the base with the Shriver formation, which is arenaceous at the contact. The Shriver is 115 feet thick, typical, very fossiliferous, and overlies 30 feet of the New Scotland black shale which has become fissile.

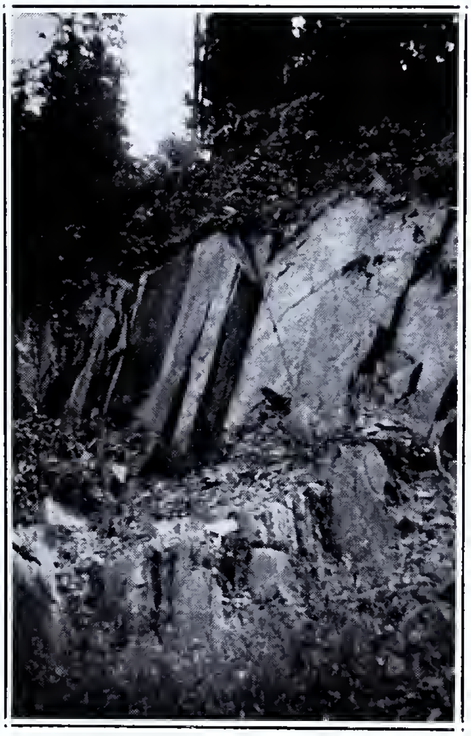
At Mount Eagle, Centre County, 48 miles northeast of Hollidaysburg, the Ridgeley is 50 feet thick, coarse, and dirty. It contains limonite and hematite at the top. The Shriver in the same section is approximately 90 feet thick. A covered interval perhaps conceals the possible presence of the New Scotland shale member.

Twenty-seven miles northeast on Pine Creek, near Jersey Shore, Lycoming County, the section is incomplete but approximately 93 feet of Ridgeley is exposed. Both uncemented sandstone and durable, calcareous Ridgeley crop out in the two limbs of the syncline. There is 81 feet of Shriver in this section, many intervals of which are concealed.



Photograph by A. B. Cleaves

Figure 23. **Mifflin Coal and Sand Company quarry, Burnham, north of Lewistown, Mifflin County. Ridgeley sandstone forms the quarry face; Shriver beds are in left foreground.**



Photograph by A. B. Cleaves

Figure 24. **Oriskany, one-half mile north of McVeytown, Mifflin County. Shriver here exposed consists of siliceous limestone and cherty beds. The Shriver reaches its maximum thickness in this area.**

One mile east of Montoursville, Lycoming County, in a complete section there is 65 feet of Ridgeley. It is clean, light colored, and loosely cemented. The Shriver is only partly exposed, but the stratigraphic interval between the Ridgeley and the New Scotland limestone would permit of 113 feet of Shriver provided there is no New Scotland black shale member. The presence of this member is suspected but lack of exposures obviates definite proof. The Shriver sections just mentioned in Centre and Lycoming counties contain considerable black, limy shale. The interval of 21 miles between the Pine Creek and Montoursville sections has no Oriskany strata indicated on the State and County geologic maps. Thicknesses, however, at both ends of this interval strongly suggest its occurrence. The reason for non-exposure is accounted for by lateral planation by the Susquehanna River and burial in its flood-plain débris.

Juniata-Susquehanna valleys. The Ridgeley varies most in thickness in the Juniata and Susquehanna valleys. From a maximum of 190 feet at Mapleton, Huntingdon County, it diminishes to zero in parts of Snyder and Montour counties, a distance of only 45 miles. At Mapleton conglomeratic beds occur, the stratigraphic positions of which vary in adjacent sections. For the most part the rock is loosely consolidated; however, some of the quarries in the Mapleton district show extremely durable sandstone, in which the cementing material is silica.

The Shriver near Mapleton is poorly exposed; it is best seen at the northwest end of the limestone quarry of the Mapleton Limestone Company opposite Mapleton, on the north side of the Juniata River. Here the Shriver is punky, buff-colored, highly fossiliferous rock. It is approximately 89 feet thick. The lower beds are concealed, so that it is not known whether the Shriver is underlain by the New Scotland shale. However, ten miles to the south on Sugar Run there are 5 feet of this shale. Consequently the latter is believed to thin out in this area.

Sections of Ridgeley sandstone in Mifflin County show a thinning northeastward. In the McVeytown-Lewistown area the sandstone ranges between 90 and 140 feet thick. The Ridgeley in both Huntingdon and Mifflin counties often holds up ridges and forms pulpit rocks although the cement is largely removed in many places. Shriver strata in Mifflin County are best shown in sections one-half and one mile north of McVeytown where the thickness is 145 feet. The beds consist of siliceous limestone, thin interbeds of shale, and thin chert beds: The latter are most common in the lower 26 feet, where nodular chert beds are also found. In the upper Shriver the limestone becomes arenaceous. Underlying the Shriver there are 13 feet of the black, fissile New Scotland shale.*

In most of Snyder, Union and Montour counties, 33 to 69 miles eastward, no Ridgeley sandstone is present. The overlying Onondaga limy shale rests directly on the Shriver formation or on basal siliceous to cherty limestones of the Ridgeley. However, nearby to the south, in parts of Juniata and Northumberland counties, a little Ridgeley sandstone occurs, nowhere over 8 feet thick. Transitional zones of thin calcareous sandstones, shales, impure cherts and siliceous limestones are present between the Ridgeley and the Shriver. Such conditions unquestionably indicate marginal facies and changes from deeper to shallow water in the Oriskany sea, or sudden rejuvenation of streams on the adjacent land masses.

At Beaver Springs, Snyder County, underlying 5 feet of Ridgeley arenaceous chert there is 101 feet of Shriver, principally a siliceous limestone, although containing many beds of gray and black chert 4 to 14 inches thick. The arenaceous chert of the Ridgeley at the top of the section weathers to a punky brown rock and is very fossiliferous. At the extreme top, under the Onondaga limy shale, there is an iron-rich zone. Underlying the Shriver is 90 feet of the black, barren New Scotland shale.

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* The black shale of the New Scotland is called Mandata by F. M. Swartz, Cf. Chap. II.

In Montour County, 2½ miles east of Danville, the Oriskany section is composed entirely of Shriver. Here the beds, 110 feet thick, are primarily black shale and black siliceous limestone, with interbedded black chert. The chert is largely contained in the upper 56 feet.

Southern and eastern areas. In southern Fulton County in a section on the west slope of Dickeys Mountain only four feet of sandstone and conglomerate can definitely be assigned to the Ridgeley. The lower part of the same section is not entirely satisfactory because of the absence of fossils. However, 20 feet of loose sand and chert and 15 feet of massive chert beds may also be Oriskany. These beds are underlain by interbedded clay and chert which contain fossils that might indicate either New Scotland or Becraft.

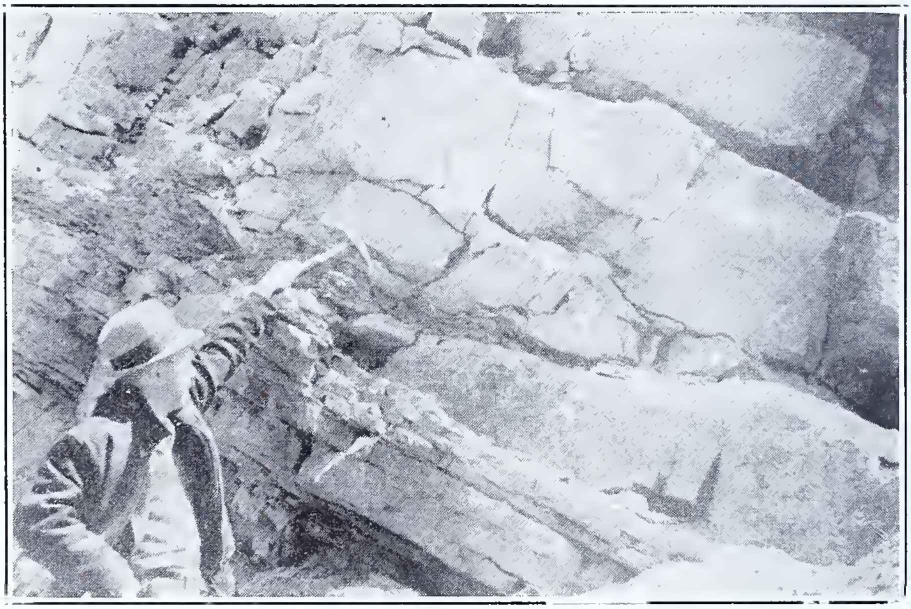
The best section of Oriskany in this region occurs in southwestern Franklin County, along State Highway 456, south of Sylvan, under the south end of the iron bridge over Licking Creek and in several small, abandoned quarries on the north side of the creek, about one-fourth mile east of the north end of the bridge. The Oriskany is all Ridgeley and consists of arenaceous limestone, calcareous sandstone and conglomerate with interlensed black chert. The Ridgeley is 52 feet thick and rests on the Licking Creek, with the Shriver missing (205).

The nearest complete section northward is at Neelyton, in southeastern Huntingdon County, where the Ridgeley sandstone is about 57 feet thick, and the underlying beds of Shriver-like lithology 109 feet thick, of which approximately 50 feet may be Shriver. The rocks in this section are weathered, hence far from ideal. The Ridgeley sandstone consists of loose sand and sandstone blocks, whereas the Shriver-like beds consist of broken-down, siliceous limestone, sand and chert blocks. The latter beds are underlain by identifiable New Scotland chert and limestone.

In Perry County there is no identifiable Shriver formation. The Oriskany consists of sandstone, conglomeratic beds, and chert. In central Perry County, in Bernheiser Ridge, 1½ miles north of Loysville, arenaceous cherts and interbedded, decomposed sandstone underlie a conglomeratic unit. The minimum thickness of the Oriskany here is 64 feet. The fauna of the arenaceous cherts is a Ridgeley "*Spirifer*" *arenosus* fauna, but the presence of a considerable number of Shriver species is indicative of a mingling of both Ridgeley and Shriver faunas. Eastward from here, along the southern and eastern line of outcrop, no Shriver fauna is encountered west of New Jersey. Consequently Perry County witnesses the disappearance of the Shriver as a factor in the Oriskany.

At Falling Springs in Perry County the Oriskany is 71 feet thick; the upper sandstone and conglomeratic member is 31 feet thick and the lower, white-weathering cherts approximately 40 feet thick. The section at Clarks Mill, approximately 5½ miles north of the Falling Springs section, and 2 miles northwest of New Bloomfield, contains Oriskany (Ridgeley) sandstone approximately 18 feet thick and white chert approximately 16 feet thick. The latter contains interbedded sandstone. The Ridgeley, "*Spirifer*" *arenosus*, fauna occurs in both members. The total thickness of the Oriskany at Clarks Mill is about 34 feet. Nearer New Bloomfield the Ridgeley sandstone is 25 and 20 feet thick in two quarries on the east and west edges of the town, respectively. In Perry County the Ridgeley is a ridge-builder, and in some sections the conglomerate is exceptionally coarse, the pebbles reaching one-fourth inch in diameter. The Ridgeley in Perry County is generally iron-rich at the upper contact.

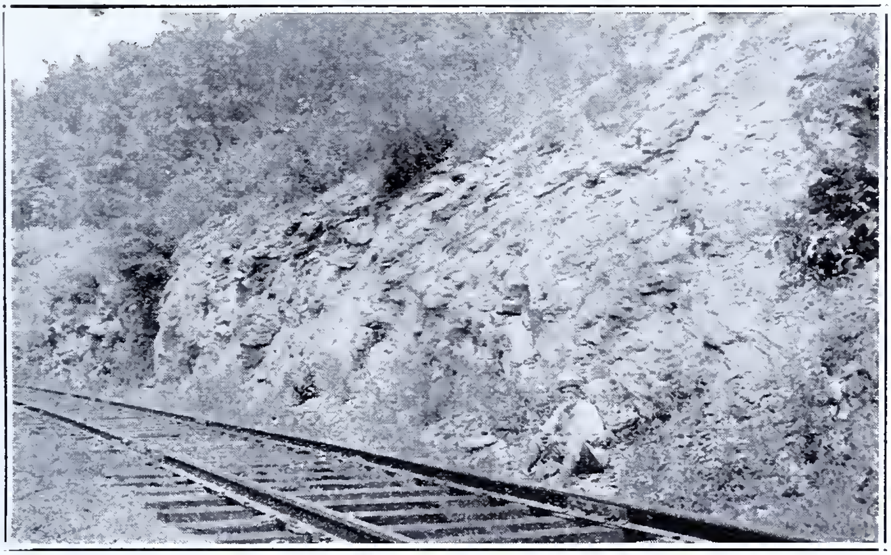
The Oriskany is probably cut out by an unconformity or fault (see page 109) in southeastern Perry County and it does not reappear along the strike until south-central Schuylkill County is attained. In Schuylkill County exposures, for the most part, are very poor and consist of loose sand, gravel and boulders. However, about one mile east of Schuylkill Haven, in the Dallego limestone quarry, and northeast of an adjacent Pennsylvania Railroad cut, up-hill from the quarry, a fairly satisfactory section may be studied. The Oriskany is approximately 44 feet thick, exceptionally conglomeratic with well rounded pebbles up to one-fourth inch in diameter. The rock has a speckled appearance due to the oxidation of limonite which often forms a rind on the exposed rock surfaces. Typical Ridgeley fossils were found. In this area the Oriskany is overlain by Onondaga limestone and underlain by greenish, siliceous shale and greenish quartzitic sandstone. The latter beds 14 feet 8 inches thick have displaced the upper Helderberg formations.



Photograph by Bradford Willard

Figure 25. **Base of Oriskany (Ridgeley) sandstone in Dallego quarry near Schuylkill Haven, Schuylkill County.**

No satisfactory section of Oriskany occurs in Carbon County except at Little Gap, through Chestnut Ridge in the eastern part of the county, 8 miles east of Palmerton. The thick, conglomeratic sandstones with the associated underlying cherts in the vicinity of Bowmanstown, Palmerton and Little Gap, in the past believed to be Oriskany, have been shown recently to be post-Oriskany (206). The fauna contained in the cherts has been demonstrated to be lower Middle Devonian rather than Lower Devonian or Oriskanian. The Oriskany conglomeratic sandstone is present in this region, however, but underlies the post-Oriskanian Palmerton sandstone, and Bowmanstown chert just mentioned. A detailed explanatory section later in this chapter shows the relationships and describes the strata at greater length. The Oriskany sandstone, containing an abundant Ridgeley fauna, is 25 feet thick in the Little Gap section and is underlain by approximately 25 additional feet of gray, cross-bedded, argillaceous, non-fossiliferous sandstone. These underlying beds are also believed to be Oriskany, because the known very fossiliferous New Scotland strata in the immediate area consist of white chert and a high-silica, white clay. The latter is observable one mile south of Kunkletown and four miles east of Smith Gap, in Chestnut Ridge in quarries of the Universal Atlas Cement Company.



Photograph by A. B. Cleaves

Figure 26. **Cut on Erie Railroad, Minisink Mills, Monroe County, along east side Brodhead Creek. The Oriskany sandstone lies under thick bushes one-half inch from the left margin of the photograph. In right foreground is upper Helderberg, Professor Swartz seated at an ostracod zone.**

In Monroe County the Oriskany is exposed on the southern slope of Cherry Ridge, and in the crest east of Saylorsburg. It is also exposed in Godfrey Ridge on the south bank of Brodhead Creek, in a cut of the Erie (New York, Susquehanna & Western) Railroad half a mile west of Minisink Mills, on the northwest bank of Brodhead Creek in the cut of the Delaware, Lackawanna & Western Railroad, where it is overpassed by the New York, Susquehanna & Western, in the crest of Godfrey Ridge above the Minisink Paper Mills, and in the gap through the ridge made by Brodhead Creek, on the east bank in the cut of the Erie (New York, Susquehanna & Western) Railroad. The latter locality, formerly known as Experiment Mills, shows an exposed section of nearly 1,000 feet which includes strata from the Esopus to the Coeymans. The Oriskany beds in this section are 120 feet thick and may be separated into two lithologic units. The upper unit consists of calcareous sandstones, siliceous limestones, and beds of black chert. This unit containing a *"Spirifer" arenosus* fauna is 55 to 60 feet thick; its base is placed at the lowest bed of sandstone. The second, underlying lithologic unit consists of siliceous limestone, arenaceous and calcareous shale, and interbeds of black chert and chert nodules. The shales are strongly sheared near the base. The exact contact with the New Scotland formation is not certain, although a New Scotland fauna is identifiable 10 feet below the supposed contact. The latter is marked by a zone of *Dalmanites* and ostracoda which do not appear to be Oriskanian. The stratigraphic thickness of the Oriskany beds underlying the lowest sandstone is 60 feet.

CONTACTS

Upper Ridgeley contact. The upper contact of the Ridgeley formation is always sharp. Except in the region east of the Schuylkill River, in Schuylkill County, it is overlain by the Needmore limy shales of the Onondaga group. Frequently the top of the Ridgeley contains considerable limonite and hematite. This is secondary and has been derived from the few inches, to one or two feet, of red shales just under the Onondaga. The presence of this iron-enriched zone so often found at the top of the Oriskany, added to the great variation in thickness (sometimes the total absence of the Ridgeley sandstone), and the complete faunal break between the Oriskany and the Onondaga, indicate a disconformity.

East of the Schuylkill River the upper contact is concealed to Carbon County. Here the Oriskany sandstone is overlain by the Bowmanstown chert and the Palmerton sandstone. The former contains a Middle Devonian fauna, the latter is barren except for some large cup corals of unknown genus and species. The Palmerton sandstone has for many years been mistaken for the Oriskany sandstone, but the relationship of these beds has recently been made clear (206).

In eastern Monroe County the Oriskany is overlain by the Esopus shales ("grit"). On Brodhead Creek 316 feet plus of Esopus disconformably overlies the Oriskany. The sparse fauna contained in the Esopus closely allies it to the Onondaga, with which Willard has recently grouped it (251). The Esopus in eastern Monroe County and northwestern New Jersey is believed to be contemporaneous with the Bowmanstown chert and the Palmerton sandstone.

Ridgeley-Shriver contact. The contact of the Ridgeley with the Shriver is sharp locally, but more commonly it is gradational. The upper beds of the Shriver commonly are arenaceous and in many localities, notably in Juniata and Northumberland Counties, interbedding of Ridgeley sandstone and Shriver siliceous limestone, chert, and shale is common.

Shriver-Helderberg contact. Along the Allegheny Front, and in much of the Juniata-Susquehanna Valley region, the Shriver, where clearly exposed, rests on a black calcareous splintery shale. This is barren except in Bedford County. In a section at Hyndman, limy black shales immediately overlying the New Scotland limestone and replete with *Schuchertella woolworthana, Eatonia medialis,* and *Anoplotheca concava,* are succeeded by a black, fissile shale containing two separate species of *Lingula*, and a *Styliolina*. The fissile calcareous black shale, a few inches thick, is overlain by 25 feet of non-fissile black shale which contains abundant *Ambocoelia umbonata,* and an occasional *Strophonella? radiata*. The last mentioned black shale becomes siliceous near the top and is gradational into the Shriver. The black shales here mentioned are tenatively placed in the New Scotland. (*Cf.* Mandata shale, Chap. II.)

In Perry, Schuylkill, Carbon and Monroe counties where there is no distinguishable Shriver formation, the Oriskany rests directly on the Helderberg. In Schuylkill County, at Schuylkill Haven, it is the Oriskany sandstone that rests on the Helderberg. In Perry County white cherts carrying a Ridgeley fauna rest on yellow cherts containing a New Scotland fauna. In Monroe County the lowest Oriskany beds, siliceous limestones and calcareous shales and cherts, grade almost imperceptibly into calcareous New Scotland shales. In some areas in the State the Shriver or lower Oriskany beds rest disconformably on the Helderberg; in other areas no hiatus is apparent.

THE ORISKANY FAUNA

The fauna of the Oriskany group is distinctive. It has definite affinities with the Helderberg fauna, but fails almost completely to extend above the Oriskany into the Onondaga and Middle Devonian. It has been shown that the Oriskany group in central and south-central Pennsylvania may be divided on the basis of lithology into two formations, the Ridgeley and the Shriver. Each of these formations has its own fauna. In part each fauna differs from the other, and yet they are intimately associated, and each is definitely Oriskanian.

The Helderbergian influence is seen in the fauna of each. Of the Ridgeley 18 percent and of the Shriver 23 percent of the fauna is found in the Helderberg. These percentages may be modified slightly if one considers that such species as *Anoplotheca flabellites, Cyrtina rostrata, Meristella lata,* and *Platyceras gebhardi*, reported as coming up into the Oriskany from the Helderberg, and included in the percentage, are generally considered as distinctive Oriskany fossils.

Only 4 percent of the Oriskany fauna passes upward into the Onondaga. Because all the species included within this figure are long-range forms it is safe to say that the Oriskany fauna was obliterated before Onondagan deposition. Whereas this is true in Pennsylvania, Dunbar believes that there was not a complete extinction of the Oriskany in western Tennessee where he recognizes a commingled Oriskany and Onondaga fauna in the Camden chert. The latter is identified with the Onondaga because of its dominant Onondagan fauna and the presence of unquestionable upper Oriskany in the underlying Quall limestone and Harriman novaculite (83).

Table XVI lists the Oriskany species in Pennsylvania and shows their distribution between the Shriver and Ridgeley and in similar Oriskany strata in the adjacent states of Maryland, New York and New Jersey. The histogram, Figure 27, illustrates the same thing in a graphic manner.

In another histogram, Figure 28, the total number of species in Pennsylvania, New York, New Jersey, and Maryland, in the Oriskany and its subdivisions is illustrated. The total species from Pennsylvania, Maryland and New Jersey, and from the Glenerie and Beecraft Mountain faunas are relatively close in numbers with two exceptions. The Shriver of Maryland, notably deficient in the number of species, and the general New York Oriskany column, are far out of proportion. Undoubtedly the list of species from the Maryland Shriver can be considerably enlarged by further detailed study. The figures that give the number of species from New York are taken from lists in old reports in which many fossil identifications can stand revision. On the basis of more recent accounts involving Oriskany strata, the total Oriskany identifiable species in that State is believed to be between 100 and 125. The above statistics give an average Oriskany fauna of 108 species for New York, Pennsylvania, Maryland and New Jersey.

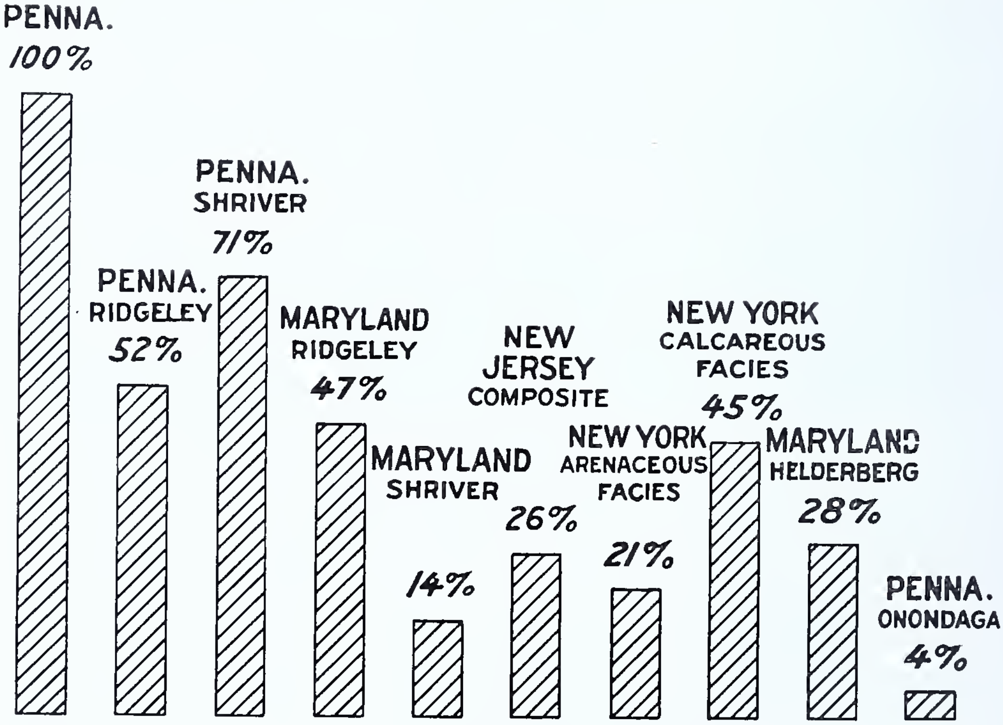


***Figure 27.* Histogram of the Oriskany fauna of Pennsylvania and percentages of this fauna found in other states and in the Shriver and Ridgeley of Pennsylvania and Maryland.**

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[*] G. A. Cooper questions the identifying of the Camden chert with the Onondaga and believes it and the Clear Creek chert of Illinois may both be Oriskany: Personal communication.

TABLE XVI. ORISKANY FAUNAS IN PENNSYLVANIA

Fauna	Pennsylvania				Maryland		N. J.	New York	
	Shriver	Ridgeley	Helderberg	Onondaga	Shriver	Ridgeley	Composite	Arenaceous	Calcareous, including "Glenerie" fauna
Zaphrentis roemeri M. Edwards & Haime	------	x	------	------	------	x	------	------	------
Z. sp. ind.	------	x	------	------	------	------	------	------	x
Favosites conicus Hall	------	x	x	------	------	x	------	------	------
F. (?) *schriveri* (Herzer)	------	x	------	------	------	x	------	------	------
Trachypora oriskania Weller	x	------	------	------	------	------	x	------	------
Crinoid columnals	x	x	x	x	------	------	------	------	x
Thysanocrinus cf. *eugenius* Ohern	------	x	------	------	------	x	------	------	------
Technocrinus spinulosus (Hall)	------	x	------	------	------	x	------	------	------
Edriocrinus sacculus Hall	x	x	------	------	------	x	x	------	x
E. poecilliformis Hall	------	x	x	------	------	------	------	------	------
Lingula sp. ind.	x	------	x	------	------	------	x	------	------
Orbiculoidea roederi Schuchert	x	------	------	------	------	x	------	------	------
O. jervensis Barrett	x	------	------	------	------	------	x	------	x
Pholidops multilamellosa Schuchert	x	------	------	------	x	------	?	------	------
P. tumida Schuchert	x	------	x	------	------	------	------	------	------
P. ovata Hall	x	------	x	------	------	------	x	------	x
Lingulapholis terminalis (Hall)	x	------	------	------	------	x	------	x	x
Platyorthis planoconvexa (Hall)	x	x	x	------	------	x	------	------	x
Rhipidomella oblata (Hall)	x	------	x	------	------	------	x	------	x
R. musculosa (Hall)	x	x	------	------	------	x	?	x	x
R. cf. *marylandica* Schuchert	------	x	------	------	------	x	------	------	------
Leptaena rhomboidalis (Wilckens)	x	x	x	x	------	------	x	x	x
L. rhomboidalis var. *ventricosa* (Hall)	------	x	------	------	------	x	x	------	x
Stropheodonta demissa (Conrad)	------	x	------	x	------	x	------	------	------
S. (Leptostrophia) beckii (Hall)	------	?	x	------	------	x	x	------	x
S. cf. *planulata* (Hall)	?	------	x	------	------	------	------	------	------
S. arctimuscula Schuchert	x	------	------	------	x	------	------	------	------
S. (Leptostrophia) magnifica (Hall)	x	x	------	------	------	x	x	x	x
S. oriskania Clarke	x	------	------	------	------	------	------	------	x
Brachyprion cf. *majus* Clarke	x	------	------	------	------	------	------	------	x
Strophonella punctulifera (Conrad)	x	------	x	------	------	------	------	------	------
Schuchertella becraftensis (Clarke)	x	x	------	------	x	x	------	------	x
S. sp. ind.	------	x	------	------	------	------	------	------	------
Hipparionyx proximus Vanuxem	------	x	------	------	------	x	x	x	x
Chonetes rowei Schuchert	x	------	------	------	------	x	------	------	------
C. hudsonicus Clarke	x	x	------	------	x	x	x	------	x
Anoplia nucleata (Hall)	x	?	x	x	x	x	x	x	x
Chonostrophia complanata (Hall)	x	x	------	------	------	x	x	x	x
Plethorhyncha speciosa (Hall)	------	x	------	------	------	x	------	------	------
Straelenia barrandi (Hall)	------	x	------	------	------	x	x	x	x
S. barrandi var. *fitchana* (Hall)	------	x	------	------	------	x	------	x	x
S. pleiopleura (Conrad)	------	x	------	------	------	x	------	x	x
Uncinulus vellicatus (Hall)	x	?	x	------	------	------	------	------	------
Eatonia peculiaris (Conrad)	x	x	x	------	------	x	x	x	x
E. medialis (Vanuxem)	------	?	x	------	x	x	x	------	x

TABLE XVI. ORISKANY FAUNAS IN PENNSYLVANIA—Continued

Fauna	Pennsylvania				Maryland		N. J.	New York	
	Shriver	Ridgeley	Helderberg	Onondaga	Shriver	Ridgeley	Composite	Arenaceous	Calcareous, including "Glenerie" fauna
E. sinuata Hall	------	x	------	------	------	x	------	------	------
Rensselaeria avaides (Eaton)	------	x	------	------	------	------	------	x	x
R. marylandica Hall	------	x	------	------	------	x	------	------	------
R. (Beachia) cumberlandiae (Hall)	------	x	------	------	------	x	------	------	------
R. (Beachia) suessana (Hall)	x	x	------	------	*	x	x	x	x
R. (Beachia) avalis (Hall)	x	x	------	------	------	x	------	x	x
Oriskania lucerna Schuchert	x	x	------	------	------	x	------	------	------
Atrypa reticularis (Linnaeus)	------	x	x	x	------	x	------	------	------
"Spirifer" cumberlandiae Hall	------	x	------	------	------	x	------	------	------
"S." tribulis Hall	x	x	------	------	x	x	------	------	x
"S." murchisoni Castelnau	x	x	------	------	------	x	x	x	x
"S." hartleyi Schuchert	------	x	------	------	------	x	------	------	------
"S." arenasus (Conrad)	x	x	------	------	x	x	x	x	x
Elytha saffardi Hall	x	x	------	------	------	------	------	------	x
Metaplasia plicata Weller	x	x	------	------	x	------	x	------	------
Crytina rastrata (Hall)	------	x	x	------	------	x	x	x	x
Tremataspira multistriata (Hall)?	x	x	x	------	------	------	------	------	x
Nucleospira ventricosa (Hall)	------	x	x	------	------	------	------	------	x
N. cf. *elegans* Hall	?	------	x	------	------	x	------	------	x
Anaplotheca dichotoma (Hall)	x	x	------	------	------	x	x	------	x
A. concava (Hall)	x	x	x	x	------	------	------	------	x
A. fimbriata (Hall)	x	x	------	------	------	x	------	------	------
A. flabellites (Conrad)	x	x	x	------	x	x	x	x	x
Meristella lata (Hall)	x	x	x	------	------	x	x	x	x
M. lentiformis Clarke	x	------	x	------	x	x	------	------	x
M. rastellata Schuchert	------	x	------	------	------	x	------	------	------
M. sp. ind. (cf. *"gigantea"* Md. Survey—*namen nudem*)	------	x	------	------	------	x	------	------	------
Actinopteria cammunis (Hall)	x	x	x	------	------	x	------	------	x
A. textilis (Hall)	x	x	x	------	------	------	x	------	x
A. textilis var. *arenaria* (Hall)	------	x	------	------	------	x	x	x	x
A. cf. *virginica* Ohern	x	------	------	------	------	x	------	------	------
Megambania lamellosa Hall	x	------	------	------	------	x	------	x	x
Loxanema sp. ind.	------	x	x	?	------	------	------	------	------
Orthonychia tartuosum (Hall)	x	x	------	------	------	x	x	x	x
Platyceras nadosum Conrad	------	x	------	------	------	x	------	x	x
P. gebhardi Conrad	x	x	x	------	------	x	------	x	x
P. gebhardi var. *ventricosum* Conrad	------	x	------	------	------	x	------	------	------
P. subfalcum Ohern	------	x	------	------	------	x	------	------	------
P. spirale Hall	------	x	x	------	------	------	------	------	------
P. subcanicum Ohern	------	x	------	------	------	x	------	------	------
P. newberryi Hall	x	x	------	------	------	x	------	------	------
Diaphorostoma ventricosum (Conrad)	?	x	x	------	------	x	x	x	x
D. desmatum Clarke	x	x	------	------	x	------	x	------	x
Tentaculites acus Clarke	x	------	x	------	------	------	------	------	x
T. aculus Hall	x	------	x	------	x	------	x	x	x
T. elangatus Hall	x	x	x	------	x	------	x	x	x
T. reedsi Vokes	x	------	------	------	------	------	------	------	------

* Variety.

Table XVI. Oriskany Faunas in Pennsylvania—Continued

Fauna	Pennsylvania				Maryland		N. J.	New York	
	Shriver	Ridgeley	Helderberg	Onondaga	Shriver	Ridgeley	Composite	Arenaceous	Calcareous, including "Glenerie" fauna
Conularia pyramidalis Hall	x	------	x	------	------	------	------	------	------
Conularia huntiana Hall	x	------	x	------	------	------	------	------	------
Phacops sp. ind.	x	------	------	?	------	x	x	------	*
Homalonotus sp. ind.	x	------	------	------	------	x	------	*	------
Dalmanites dentatus Barrett?	x	------	x	------	------	------	x	------	x
D. pleuroptyx (Greene)	x	?	x	------	------	------	------	------	x
Acidaspis tuberculata (Conrad)	x	------	x	------	------	------	------	------	x
Paraschmidtella dorsopunctata Swartz	x	------	------	------	------	------	------	------	------
Aechmina bigeneris Swartz	x	------	------	------	------	------	------	------	------
A. spinoterminata Swartz	x	------	------	------	------	------	------	------	------
Primitiella (?) *ventricosa* Swartz	x	------	------	------	------	------	------	------	------
Pyxiprimitia ventriclefta Swartz	x	------	------	------	------	------	------	------	------
P. ventripunctata Swartz	x	------	------	------	------	------	------	------	------
Parabolbina limbata Swartz	x	------	------	------	------	------	------	------	------
P. ventrispinosa Swartz	x	------	------	------	------	------	------	------	------
Bollia sagittaformis Swartz	x	------	------	------	------	------	------	------	------
B. burgeneri Swartz	x	------	------	------	------	------	------	------	------
B. americana Ulrich & Bassler	x	------	------	------	x	------	------	------	------
B. americana var. *zygocornis* Swartz	x	------	------	------	------	------	------	------	x
B. cristata Swartz	x	------	------	------	------	------	------	------	------
Ulricha affinis Bassler & Kellett	x	------	------	------	------	------	------	------	------
U. pluripunctata Swartz	x	------	------	------	------	------	------	------	------
U. terminata Swartz	x	------	------	------	------	------	------	------	------
Acanthoscapha pentagonalis Swartz	x	------	------	------	------	------	------	------	x
Tubulibairdia tubulifera Swartz	x	------	------	------	------	------	------	------	x
Parahealdia (?) *centralis* Swartz	x	------	------	------	------	------	------	------	------
Cavellina paraguaesita Swartz	x	------	------	------	------	------	------	------	------
Thlipsura confluens Swartz	x	------	------	------	------	------	------	------	------
T. robusta Ulrich & Bassler	x	------	------	------	x	------	------	------	------
T. robusta var. *tricornis* Swartz	x	------	------	------	------	------	------	------	------
Thlipsurella oblonga Ulrich & Bassler	x	------	------	------	x	------	------	------	------
T. ellipscoclefta Swartz	x	------	------	------	------	------	------	------	------
T. secoclefta Swartz	x	------	------	------	------	------	------	------	------
T. curtinensis Swartz	x	------	------	------	------	------	------	------	------
T. crateriformis Swartz	x	------	------	------	------	------	------	------	------
T. orthoclefta Swartz	x	------	------	------	------	------	------	------	------
Octonaria deltisulcata Swartz	x	------	------	------	------	------	------	------	------
O. dorsosulcata Swartz	x	------	------	------	------	------	------	------	------

* Variety.

Many species common in the Shriver do not appear in the Ridgeley and *vice versa.* For example, among the more common forms 31 species of ostracoda abundant in the Shriver have never been found in the Ridgeley. This is no doubt chiefly due to the arenaceous nature of the Ridgeley which is an unsuitable medium for the preservation of such minute and delicate fossils. Other more abundant species never found in the Ridgeley are *Orbiculoidea jervensis, Stropheodonta arctimuscula, S. punctulifera, Tentaculites acus;* and *T. aculus.* Some species that are generally considered Shriver forms but occasionally are found up in the Ridgeley include *Metaplasia plicata* and *Schuchertella becraftensis.*

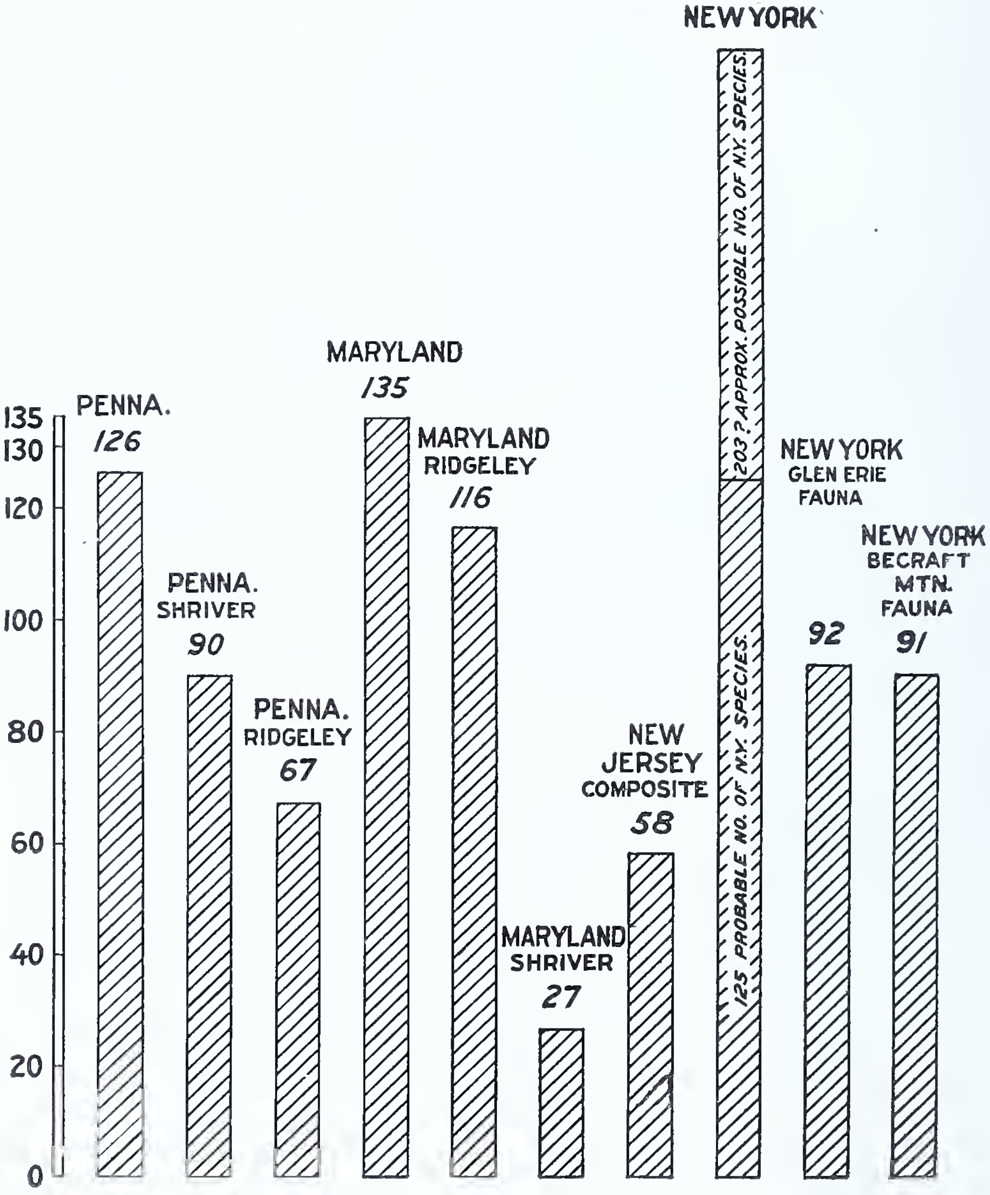

Figure 28. **Histogram to illustrate the distribution of the total number of Oriskany species in Pennsylvania, New York, New Jersey and Maryland.**

Of the more common Ridgeley species never found in the Shriver *Hipparionyx proximus, Straclenia barrandii, Rensselaeria marylandica, R. ovoides, Actinopteria textilis* var. *arenaria*, and *Platyceras subconicum* are the chief forms. Common in the Ridgeley but occasionally found in the Shriver are *"Spirifer" arenosus, Stropheodonta magnifica*, and *Anoplotheca fimbriata.*

Species common in both Shriver and Ridgeley include *Edriocrinus sacculus, Platyorthis planoconvexa, Chonetes hudsonicus, Eatonia peculiaris, Rensselaeria ovalis, "Spirifer" murchisoni, Orthonychia tortuosa, Anoplotheca flabellites*, and *Platyceras gebhardi.*

The Shriver formation, consisting of impure siliceous limestone, impure chert, and both siliceous and calcareous shale, may be considered as representing a deep-water phase of the Oriskany. Lithologically there is no great change from the Upper Helderberg deposits except that the siliceous content of the Shriver is generally greater. The Shriver is abundantly fossiliferous, the fossils occurring chiefly in the middle and upper beds. Attempts at zoning have been tried but have not proved successful. However, future intensive zoning efforts, based principally upon the ostracoda, may be possible.

The "Oriskany" white clays formerly thought to occur in Carbon and Monroe Counties as well as in Huntingdon County, are now known to be restricted to Huntingdon. The deposits in Carbon and Monroe Counties occur in the upper Helderberg. The Huntingdon County Oriskany white clays are in the Shriver formation and have been described earlier in this chapter. The fauna is typically that of the Shriver and the specimens are beautifully preserved as molds and casts.

White clay faunule, quarry of the Alexandria Fire Clay Company, three miles southeast of Alexandria, Huntingdon County.

Traychypora oriskania Weller, r
Pholidops multilamellosa Schuchert, a
Stropheodonta cf. *planulata* (Hall), r
S. sp. ind.
Schuchertella becraftensis (Clarke), c
Chonetes hudsonicus Clarke, c
C. sp. ind.
Anoplotheca fimbriata (Hall), c
A. flabellites (Conrad), c
Meristella lentiformis Clarke, r
Metaplasia plicata Weller, a
Oriskania lucerna Schuchert, r
Rensselaeria suessana (Hall), r
Conularia cf. *pyramidalis* Hall, r
Tentaculites reedsi Vokes, c
Platyceras gebhardi Conrad, r
P. sp. ind.
Bollia americana var. *zygocornis* Swartz, a
B. sagittaformis Swartz, c
Tubulibairdia tubulifera Swartz, a
Acanthoscapha pentagonalis Swartz, a
Thlipsurella oblonga Ulrich & Bassler, c
Dalmanites sp. ind., c

---

a - abundant, c - common, r - rare.

The presence of both Shriver and Ridgeley in Perry County has been a problem that has perplexed investigators. Lithologically the Oriskany is divisible into conglomeratic sandstone and medium-grained sandstone above and white chert and arenaceous chert below. Such units hold in the eastern part of the county, but in the central portion in the vicinity of Kistler and Loysville the sandstone and cherty beds are interbedded. With the exception of the Loysville area the fauna of both the white cherts and the overlying sandstone and conglomeratic sandstone is a Ridgeley fauna. F. M. Swartz secured ostracoda from the white cherts, but they were not characteristic Shriver species (personal communication).

Northeast of Loysville 1½ miles, in Bernheiser Ridge, Oriskany sandstone and yellowish and white arenaceous chert are interbedded. A large fauna is present and occurs chiefly in the cherts. The fauna is mixed Ridgeley and Shriver, such species as *Metaplasia plicata*, *Pholidops multilamellosa*, occurring with "*Spirifer*" *arenosus*, *Straelenia pleipleura*, *Cyrtina rostrata*, etc. In spite of this commingling the presence of the Shriver as a formation in Perry County is doubtful. Characteristic Shriver fossils are, for the most part, absent, and the occurrence of typical Ridgeley forms throughout the cherty beds is significant. Because of its peculiar interest the Oriskany fauna at Loysville is listed below:

Oriskany fauna at Loysville, Perry County

Technocrinus spinulosus (Hall), r
Pholidops cf. *multilamellosa* Schuchert, r
Platyorthis planoconvexa (Hall), r
Rhipidomella cf. *oblata* (Hall), r
Leptaena rhomboidalis (Wilckens), r
Stropheodonta demissa (Conrad), r
Schuchertella becraftensis (Clarke), r
Chonostrophia complanata (Hall), r
Straelenia pleipleura (Conrad), r
Stenochisma formosa (Hall), r
Eatonia peculiaris (Conrad), r
Rensselaeria cumberlandiae (Hall), r
R. suessana (Hall), c
R. ovalis (Hall), c
Oriskania lucerna, Schuchert, r
"*Spirifer*" *murchisoni* Castelnau, a
"*S.*" *arenosus* (Conrad), c
Metaplasia plicata Weller, c
Cyrtina rostrata (Hall), r
Nucleospira ventricosa (Hall), r
Anoplotheca concava (Hall), r
A. flabellites (Conrad), c
Meristella lata (Hall), a
M. sp. ind.
Actinopteria textilis var. *arenaria* (Hall), r
Tentaculites elongatus Hall, r
Platyceras gebhardi Conrad, c
Diaphorostoma desmatum Clarke, a

---

a - abundant, c - common, r - rare.

CORRELATION

The Ridgeley and Shriver faunas are both definitely Oriskanian and may be correlated with the *gaspensis*-fauna. The *gaspensis*-fauna derives its name from the Moose River sandstone fauna in Maine, characterized by "*Spirifer*" *gaspensis*. A recent paper by R. S. Allan (1) devotes considerable space to the study of the correlation and relationships of Upper Silurian and Lower Devonian faunas in northeastern America and western Europe. In this excellent paper Allan correlates in the "*gaspensis*"-fauna those Oriskanian faunas found in the Moose River sandstone of Maine, the Gaspé sandstone and Grand Grève limestone of Quebec, the Oriskany sandstone of New York, and the Ridgeley and Shriver of Maryland. To this list may be added the fauna of the Littleton formation in New Hampshire, the Glenerie and Becraft Mountain faunas (calcareous Oriskany) of New York, the faunas of the "*Spirifer*" *murchisoni* and *Orbiculoidea jervensis* zones of the New Jersey Oriskany, the faunas of the Ridgeley and Shriver of Pennsylvania, the Oriskany sandstone of Virginia, the Ridgeley and Shriver and prob-

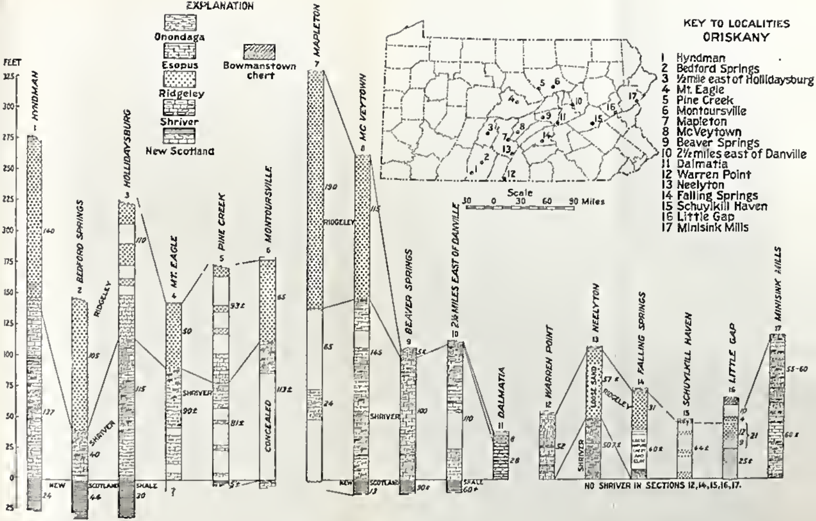

Figure 29. Correlation chart of Oriskany group in Pennsylvania.

ably also the Huntersville chert of West Virginia. Other faunas that can likewise be correlated with the *gaspensis*-fauna are those from the Quall limestone, the Harriman novaculite, and possibly the overlying Camden chert in western Tennessee. The Clear Creek chert in Illinois is the northward extension of the Camden, hence its fauna likewise may possibly be correlated with the *gaspensis*-fauna. As has been pointed out earlier in the chapter, some question exists concerning the Oriskany age of the Camden and Clear Creek cherts; consequently, until the Oriskany correlation of these formations is definitely decided, they are only tentatively included here. In Missouri the Little Saline limestone is definitely correlated with the *gaspensis*-fauna.

The *gaspensis*-fauna contains in the Moose River sandstone such characteristic fossils as *"Leptostrophia perplana"* (probably stropheodontas of the *S. magnifica* type), *"Spirifer" murchisoni, "S." gaspensis, Antispirifer harroldi, Anoplotheca flabellites,* and *Follmannella mainensis.*

Allan lists fifteen typical Ridgeley species from Maryland as essentially agreeing with the *gaspensis*-fauna. He also lists seven common Shriver species which he calls the *tribulis*-sub-fauna after *"Spirifer" tribulis,* but which he says is not essentially distinct from the *gaspensis*-fauna. He cites lists from the Ridgeley and Shriver of Maryland that can be duplicated with Ridgeley and Shriver species from Pennsylvania, hence the similar formations may be claimed to correlate with the *gaspensis*-fauna.

He continues and correlates Oriskany faunas of eastern North America with faunas of western Europe, as follows:

> As far as comparison with western European communities is possible, the characteristic fossils of the arenaceous horizons represented by the Moose River sandstone, the Gaspê sandstone, and the Oriskany sandstone of New York, suggest the *hercyniae*-fauna of Lower Emsian [Coblentzian] age. This correlation is based chiefly on the presence in these American strata of Spirifers of the *hercyniae*-type *(S. gaspensis, S. murchisoni)*, and of Leptostrophias of the *explanata*-type *(L. magnifica* and its varieties).
>
> It has been shown that the fauna of these American arenaceous horizons is essentially similar to that of the calcareous Oriskany strata in Maryland. Of the twenty-four species cited as characteristic of one or other of the arenaceous horizons, seven occur in the calcareous Oriskany of Maryland.
>
> If these conclusions are legitimate, then an important fact emerges. The *gaspensis*-fauna of the calcareous facies in Maryland is the equivalent of the *hercyniae*-fauna of psammopelitic facies in western Europe.

Allan points out also that in a sequence of open-water calcareous facies, from the aspect of faunal chronology there are no sharp faunal boundaries. For example, the sequence of faunas is transitional and gradual from the Coeymans into the New Scotland, the New Scotland into the Shriver, and the Shriver into the Ridgeley. This fact has already been demonstrated earlier in the chapter where it has been shown that 18 per cent of the Ridgeley and 23 per cent of the Shriver faunas in Pennsylvania are found in the Helderberg.

Table XVII. Oriskany Correlations*

Western European fauna	Quebec	Maine	New Hampshire
HERCYNIAE	Gaspé sandstone Grand Grève limestone Div. 7 & 8	Moose River sandstone	Littleton formation

New York	New Jersey	Pennsylvania	Maryland	Virginia
Oriskany ss. Glenerie Becraft Mtn.	"*Spirifer*" *murchisoni* zone. *Orbiculoidea jervensis* zone.	Ridgeley Shriver	Ridgeley Shriver	Oriskany sandstone

West Virginia	Western Tennessee	Illinois	Missouri	N. American fauna
Huntersville chert Ridgeley Shriver	(Camden chert)? Harriman novaculite Quall limestone	(Clear Creek chert)?	Little Saline limestone	GASPENSIS

Note: The *Dalmanites dentatus* zone, the basal Oriskany in New Jersey, by the presence of "*Spirifer*" *cyclopterus* shows a mixing of the *gaspensis*-fauna with the older *cyclopterus*-fauna. Consequently its faunal chronology is older and it cannot be exactly correlated with the *hercyniae-gaspensis* fauna.

Lack of positive data on the faunas of the Armuchee chert and the Frog Mountain sandstone of Georgia, and the Jemison chert and the Frog Mountain sandstone of Alabama prevents their inclusion in the correlation table.

Allan selected the Maryland Upper Silurian-Lower Devonian stratigraphic column as the unit of comparison for faunas of the calcareous facies. He selected the Maryland column in preference to that in New York because "the relation of pre-Coeymans units in New York—Manlius, Rondout, Cobleskill, etc.—to those of Maryland is a thorny problem, concerning which American geologists—Weller, Ulrich, Hartnagel, and others—present most discordant views" (1). He also pointed out that whereas the sequence in Bohemia is classic, it is imperfectly known.

Certainly equal to the sequence of Maryland Upper Silurian-Lower Devonian strata as a unit of comparison for faunas of the calcareous facies, and perhaps superior, is the similar sequence in south-central and central Pennsylvania. The development of the Shriver and the knowledge of its fauna is much better in Pennsylvania. The better exposures of weathered strata in the Shriver and the recent detailed studies of F. M. Swartz of Shriver faunas, and the ostracoda in particular, make Pennsylvania the classic region to study Helderberg-Oriskany relationships. It is fortunate that this is true, because for the first time opportunity is afforded detailed correlations between the Oriskany strata, arenaceous and calcareous, in New York and New Jersey, and the Oriskany Shriver-Ridgeley faunas of Maryland.

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* Adapted from Allan's paper.

LOCAL SECTIONS OF THE ORISKANY GROUP

The following sections were measured during the field seasons of 1936 and 1937. The section at Minisink Mills, on Brodhead Creek in Monroe County, was visited several times, once in the company of F. M. Swartz, who helped establish the Oriskany-Helderberg contact. The sections at Hyndman and Little Gap were remeasured and studied in 1938, and the section at Dallego quarry, near Schuylkill Haven in Schuylkill County, was studied and measured for the first time in 1938.

The Shriver section on the Frankstown road about a mile northeast of Hollidaysburg is one of the finest known in the State. F. M. Swartz has described this and another Shriver section, at Mount Rock near Lewistown in Mifflin County, in the preceding chapter on the Helderberg group; consequently they are not repeated in this chapter, but the reader is asked to refer to them.

All the sections are given in descending stratigraphic order. After the name of a fossil aa means very abundant, a—abundant, c—common, r—rare, rr—very rare.

Hyndman, Bedford County

A splendid Oriskany-Helderberg section is exposed in old quarries on the northern edge of Hyndman. The quarries are immediately west of State Highway 96. The highest Oriskany (Ridgeley) is exposed west of, and continuous with the quarry section, along the tracks of the Baltimore & Ohio Railroad.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
Medium-grained, brownish to white sandstone. Contains conglomeratic beds in mere pebble bands and in beds up to two feet thick. The pebbles, primarily quartz, range up to ⅛ inch in diameter. This entire zone is fossiliferous, but is especially so in the lower 20 feet. *Edriocrinus sacculus* (c), *Thysanocrinus* cf. *eugenius* (rr), *Stropheodonta magnifica* (c), *Hipparionyx proximus* (c), *Rensselaeria marylandica* (a), *R. suessana* (a), "*Spirifer*" *arenosus* (a), "*S.*" *murchisoni* (a), *Platyceras gebhardi* (aa) occur.	55±	302
Concealed	35±	247
Calcareous, grayish sandstone, with chert nodules and layers of chert nodules, and beds of chert. At the top of this unit the Ridgeley has been folded and faulted. The sandstone is medium-grained and grades into the Shriver. *Eatonia sinuata* (rr), *E. peculiaris* (c), *Rensselaeria suessana* (c), *Anoplotheca flabellites* (c), "*Spirifer*" *murchisoni* (c), *Platyceras gebhardi* (aa) occur.	50	212

	Feet	
	Unit	Total
Shriver formation:		
Highly siliceous limestone, impure, dark gray to black, with interbeds of black chert, black chert nodules and layers of nodules. The section in the quarry is all fresh rock. The basal beds are very shaly and the fossils are largely confined to the middle and upper beds. Because of the freshness of the Shriver, fossil collecting is not very satisfactory. *Chonetes hudsonicus* (c), *Anoplotheca flabellites* (c), *Metaplasia plicata* (c), *Meristella lata* (r), "*Spirifer*" cf. *murchisoni* (r), *Dalmanites pleuroptyx* (r), *Bollia cristata* (a) were identified.	137	162
Helderberg group:		
Mandata shale		
Black slightly calcareous shale replete with *Ambocoelia umbonata* (aa), and an occasional *Strophonella? radiata* (c).	24	25
Black sooty fissile, slightly calcareous shale. *Lingula* 2 sp. ind., *Styliolina* sp. ind. (c).	1	1
Gray, highly calcareous shale, very fossiliferous, *Schuchertella woolworthana* (aa), *Anoplotheca concava* (c), *Eatonia medialis* (c).		

Bedford Springs, Bedford County

This section is exposed on the north side of State Highway 220 about 3 miles south of Bedford Springs. The Ridgeley-Onondaga contact is not exposed. An unusual feature is the thinness of the Shriver, only 40 feet, which is considerably thinner than in other sections in the county.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
Massive-bedded white, rusty-weathering medium-grained sandstone. Sparsely fossiliferous: *Rensselaeria marylandica* (c), "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (c).	105	189½
Shriver formation:		
Platy, highly siliceous, impure gray limestone, becomes cherty near the base. These cherts are somewhat arenaceous.	40	84½
Helderberg group:		
Mandata shale and New Scotland limestone:		
Fissile, sooty black shale; barren.		
Thick and thin-bedded bluish-black limestone and interbedded black chert. Very fossiliferous: "*Spirifer*" *perlamellosus* (aa), *Eospirifer macropleurus* (c).	44½	44½

Cumberland City Reservoir (Thos. W. Koon Dam), Bedford County

This section is at the northwest end of the Thos. W. Koon dam, east about 1 mile of State Highway 220, approximately 8 miles north of Cumberland, Maryland and about 6 miles south of Centerville (Bedford Valley P. O.) in Bedford County, Pennsylvania.

Sections occur at both ends of the dam, and for the Ridgeley are among the finest in the State.

	Feet	
	Unit	Total
Onondaga group:		
Needmore shale:		
Greenish soft shale, weathered yellowish green.		
Oriskany group:		
Ridgeley sandstone:		
The upper Ridgeley has been strongly weathered and is mostly broken down into loose brownish sand. Interbeds of quartz-pebble conglomerate occur in the upper part. The cementing material between the sand grains, which has been removed, was originally calcareous. "*Spirifer*" *arenosus* (c), "*Spirifer*" *murchisoni* (c), *Anoplotheca flabellites* (aa) occur.	135	172
Calcareous sandstone, bluish-gray, weathering forms pockets in the rock in which silicified fossils and sand accumulate. The lower Ridgeley beds are extremely fossiliferous: *Favosites conicus* (rr), *Technocrinus* cf. *spinulosus* (rr), *Edriocrinus sacculus* (a), *E. pocilliformis* (a), *Stropheodonta magnifica* (rr), *Platyorthis planoconvexa* (c), *Rhipidomella musculosa* (r), *Eatonia peculiaris* (c) *Anoplotheca fimbriata* (aa), *A. flabellites* (c), *Cyrtina rostrata* (rr), *Rensselaeria marylandica* (c), *R. suessana* (c), "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (c), *Platyceras gebhardi* (aa), *P. nodosum* (r), *Dalmanites* cf. *pleuroptyx* (r).	20	37
Shriver formation:		
Platy, siliceous, somewhat arenaceous, bluish-gray limestone with thin interbeds of black chert and black chert nodules. Fossils very difficult to collect because of the freshness of the rock: *Anoplotheca flabellites* (c), *Stropheodonta* sp. ind. (rr).	17	17
Concealed.		

Mount Eagle, Centre County

This section occurs in and joining the Carson sand quarry ½ mile north of the village of Mount Eagle. The quarry in the Ridgeley sandstone is about 100 yards long by 20 yards wide.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
Fine and coarse-grained brownish sandstone, occasional beds of white sandstone. The actual contact with the Onondaga is not seen, but the top beds are impregnated with limonite, and the topographic expression of the low ridge held up by the Oriskany and New Scotland, the northern slope of which is formed by the limonite-stained Ridgeley, suggests that this bed is the top of the Ridgeley. "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (c), *Rensselaeria marylandica* (c), *Platyceras gebhardi* (c) were collected.	50	144
Shriver formation:		
Between the active quarry and the crusher, the Shriver is poorly exposed. There are few concealed intervals except near the base, above the New Scotland.		
The upper beds of the Shriver consist of impure, thin-bedded chert which weathers white.	21	94

	Feet Unit	Feet Total
Underlying the chert beds the Shriver is a gray, platy, siliceous and shaly limestone. This limestone is impure and is punky near the top. *Edriocrinus sacculus* (c), *Platyorthis planoconvexa* (r), *Rhipidomella musculosa* (r), *Anoplotheca flabellites* (a), *Rensselaeria suessana* (r), *Metaplasia plicata* (r), "*Spirifer*" cf. *murchisoni* (r), *Meristella lata* (c), *Dalmanites* sp. ind. (rr). Black slightly calcareous shale is common near the bottom of the above unit.	53	73
Concealed.	20	20
Helderberg group:		
New Scotland formation:		
Interbedded black chert and bluish-black limestone in beds 3 inches to 6 inches thick.		

Jersey Shore (Pine Creek), Lycoming County

The Oriskany is exposed in road cuts about ¼ and ½ mile south of Route 220, the highway between Jersey Shore and Avis, on the east side of Pine Creek. The sequence of Oriskany strata is south of and continuous with the Helderberg sections there seen. The Ridgeley is best exposed on the north side of the Pine Creek Limestone Company quarry, ½ mile south of the highway above mentioned:

	Feet Unit	Feet Total
Oriskany group:		
Ridgeley sandstone:		
Fine-grained, iron-stained, sugary, calcareous sandstone. Weathers buff, porous; very much broken up in the bank. Traverse N39°E, 260 feet. Very fossiliferous: *Rhipidomella* cf. *marylandica* (r), *Rensselaeria marylandica* (c), *R. suessana* (r), *Hipparonyx proximus* (r), "*Spirifer*" *arenosus* (aa), "*S.*" *murchisoni* (aa).	93	174
Shriver formation:		
Thin-bedded, black, somewhat arenaceous shale. Weathers buff and grey. The Shriver is largely covered. Traverse N39 E, 220± feet. *Lingula* sp. ind. (rr), *Chonetes hudsonicus* (aa), *Anoplotheca flabellites* (c), "*Spirifer*" *murchisoni* (r). In this same section Swartz collected in addition to forms included here, *Stropheodonta arctimuscula* (c), "*Spirifer*" *triburarius* (this is probably *Metaplasia plicata*) (r), *Bollia americana* and *Thlipsura confluens*.	81±	81
Helderberg group:		
New Scotland limestone:		
Dense bluish-black limestone with interbedded chert.		
The Ridgeley sandstone exposed on the north side of the Pine Creek Limestone Company quarry is a gray, very calcareous sandstone. This section is about ¼ mile south of the previous section and is abundantly fossiliferous: "*Spirifer*" *arenosus* (a), "*S.*" *murchisoni* (a), *Anoplotheca flabellites* (c), *Oriskania lucerna* (r), *Rensselaeria* sp. ind.		

Montoursville, Lycoming County

This section is exposed 1 mile east of Montoursville in the quarry of the Lycoming Silica Sand Company. The Ridgeley is splendidly exposed here and in another small quarry ¼ mile east of the Williamsport Country Club on the north side of the State Highway between Williamsport and Muncy.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
White sugary sandstone, loosely cemented. Pebble bands common, upper 15 feet iron-stained. The contact with the overlying Needmore shale of the Onondaga group is seen at the top of the quarry. The basal beds of the Ridgeley are very cherty, the chert weathering white. They contain: *Edriocrinus sacculus* (c), *Platyorthis planoconvexa* (r), "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (c), *Anoplotheca flabellites* (c); in the Ridgeley quarry approximately 2 miles to the west other typical Ridgeley fossils are abundant: *Hipparionyx proximus* (aa), "*Spirifer*" *arenosus* (a), "*S.*" *murchisoni* (aa), *Rensselaeria ovoides* (r), *R. marylandica* (aa).	65	178
In cherty beds at the base, part of which may be Shriver, fossils are abundant: *Edriocrinus sacculus* (c), *Anoplotheca flabellites* (aa), "*Spirifer*" *tribulis* (c), *Orthonychia tortuosa* (c), *Platyceras gebhardi* (aa).		
Shriver formation:		
Mostly concealed. Possibly some of the white chert mentioned above may be Shriver. Also greenish-gray, platy silicious limestone.	113?	113
Helderberg group:		
New Scotland limestone:		
Black bedded chert, and bluish-black dense limestone: *Eospirifer macropleurus*, etc.		

Mapleton, Huntingdon County.

The Ridgeley sandstone is excellently exposed in quarries in the vicinity of Mapleton. These quarries occur both north and south of the borough. Those most accessible are across the Juniata River north of the borough. The best section of Shriver is at the northwest end of the limestone quarry of the Mapleton Limestone Company, opposite Mapleton on the north side of the Juniata River. The lower Shriver beds are concealed, the next lower strata in the section being the Keyser limestone of the Helderberg group.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
White to buff, coarse and medium-grained quartz sandstone and conglomerate. In this area the Ridgeley is so pure (chiefly quartz) that it makes a good glass sand. Some iron staining occurs along the bedding and joint planes. *Hipparionyx proximus* (r), *Eatonia peculiaris* (c), *Rensselaeria marylandica* (aa), *R. ovoides* (rr), *R. ovalis* (c), "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (aa), *Platyceras subconium* (aa).		430±

	Feet	
	Unit	Total
Shriver formation:		
Poorly exposed, weathered buff, impure siliceous and punky shale. *Metaplasia plicata* (r), near top.	65	240
Impure siliceous and punky, yellowish weathered shale. Very fossiliferous: *Pholidops multilamellosa* (aa), *Rhipidomella musculosa* (r), *Chonetes hudsonicus* (a), *Meristella lentiformis* (c) "*Spirifer*" *murchisoni* (rr), "*S.*" *tribulis* (r), *Metaplasia plicata* (aa), *Schuchertella becraftensis* (c), *Stropheodonta arctimuscula* (c), *Bollia americana* (a), *B. sagittiformis* (c). *Thlipsura robusta* (c), *Tubulibairdia tubulifera* (a).	24	175
Covered.	151±	151
Helderberg group:		
Bluish-black dense limestone.		

McVeytown, Mifflin County

One mile north of McVeytown, the Ridgeley ranges in thickness in thickness from 90 to 140 feet. The Shriver has maximum known thickness in this section.

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
White sugary sandstone with conglomeratic beds. Weathers buff. Somewhat cross-bedded and bedding planes often iron-stained. *Rensselaeria marylandica* (a), "*Spirifer*" *arenosus* (a), "*S.*" *murchisoni* (a).	90	238
Shriver formation:		
Black siliceous limestone, thin interbeds of black shale and chert, and black nodular chert beds. Because of the freshness of the rock fossil collecting is not very satisfactory. *Chonetes husonicus* (a) at 40 feet below the Ridgeley, *Metaplasia plicata* (a), especially near the middle. *Anoplotheca flabellites* (c), "*Spirifer*" sp. ind. occur:	119	145
Nodular cherts in beds and scattered in impure black calcareous and silecous shale.	26	26
Helderberg group:		
Mandata shale (?)		
Barren black fissile shale. Dense bluish-black limestone with 4-inch bed black chert at top. *Eospirifer macropleurus* (r), *Eatonia medialis* (r), *Isorthis perelegans* (r).		

Beaver Springs, Snyder County

Northeast end of Owlhead Ridge, 1/3 mile north of Beaver Springs. This section is complete with the overlying Needmore shale of the Onondaga group at the top, and the New Scotland shales and limestones of the Helderberg group at the bottom.

	Feet	
	Unit	Total
Onondaga group:		
Needmore shale:		
Thin-bedded soft shale, weathered yellowish green.		
Oriskany group:		
Ridgeley formation:		
Arenaceous chert weathered white and to a buff punky condition. An iron-enriched zone at the extreme top. *Rhipidomella* cf. *musculosa* (r), *Meristella lata* (aa), *M. rostellata* (r), *Rensselaeria suessana* (c), *Cyrtina rostrata* (r), *Anoplotheca flabellites* (a), "*Spirifer*" *murchisoni* (aa), *Platyceras gebhardi* (aa) were found.	5	201
Shriver formation:		
Impure siliceous limestone with interbeds of gray and black chert 4 inches to 14 inches thick. Brownish punky arenaceous chert at top. For the most part the rock is fresh and fossil collecting difficult. At the top *Tubulibairdia tubulifera* (c), *Bollia americana* var. *zygocornis* (c).	106	196
Helderberg group:		
Mandata shale and New Scotland formation:		
Barren black thin-bedded shale.		
Dense bluish-black limestone	90	90

Danville, Montour County

Along U. S. Highway 11 2½ miles east of Danville in the banks of a dirt road branching off to the south, a very good Oriskany section is exposed. The lithology is entirely characteristic of the Shriver and to date there is no evidence of any Ridgeley in the section.

	Feet	
	Unit	Total
Onondaga group:		
Needmore shale:		
Shale, thin-bedded, weathered yellowish green.		
Oriskany group:		
Shriver formation:		
Thin-bedded impure calcareous shale, and punky siliceous limestone, weathering buff; black fissile shale, and interbedded black chert. The latter is contained mostly in the upper 56 feet. *Orbiculoidea jervensis* (r), *Rhipidomella musculosa* (r), "*Spirifer*" *murchisoni* (r), *Anoplotheca flabellites* (c), *Meristella lata* (c), *Actinopteria textilis* var. *arenaria* (r) are present.	26	114
Concealed.		
Thin-bedded calcareous shale and interbedded 1-inch to 1-foot beds of black fissile shale. *Orbiculoidea jervensis* (c), *Chonetes hudsonicus* (c), "*Spirifer*" *tribulis* (c), *Anoplotheca flabellites* (c) occur.	28	88
Helderberg group:		
New Scotland formation:		
Black barren fissil shale.	60	60

Dalmatia, Northumberland County

This section on U. S. Highway 15 about 1 mile south of Dalmatia shows a complete section through the Oriskany. It is especially interesting because in this area where the Ridgeley sandstone is largely absent, 8 feet are exposed.

	Feet	
Onondaga group:		
Needmore shale:	Unit	Total
Thin-bedded shale, weathered yellowish green.		
Oriskany group:		
Ridgeley sandstone:		
Fine-grained sandstone, weathers yellowish: "*Spirifer*" *murchisoni* (c).	8	37
Shriver formation:		
Medium-bedded chert, weathers white to yellow, punky and impure at the base.	20	29
Punky buff-colored impure chert and siliceous limestone. Material much weathered and blocky in bank. *Pholidops multilamellosus* (c), *Lingulapholis terminalis* (r), *Eatonia* sp. ind., (r), *Leptaena rhomboidalis* (c), "*Spirifer*" *murchisoni* (r), "*S.*" *tribulis* (r), *Meristella* cf. *lentiformis* (r), *Anoplotheca flabellites* (c), *Platyceras gebhardi* (c) identified.	9	9
Helderberg group:		
Mandata shale and chert:		
Blocky impure chert, clay and shale: *Eospirifer macropleurus* (c), "*Spirifer*" *perlamellosus* (r), *Nucleospira ventricosa* (r), *Stenochisma formosa* (r).		

Warren Point, Franklin County*

The Warren Point sections occur in southwestern Franklin County on State Highway 456 where it crosses Licking Creek. The first section is under the south end of the iron bridge.

	Feet	
Onondaga group:		
Needmore shale:	Unit	Total
Thin-bedded shale, weathers yellowish green.		
Oriskany group:		
Ridgeley sandstone:		
Conglomerate with large well-rounded quartz pebbles. Calcareous cement.	½	19
Limestone, arenaceous, dark blue with bands of fine conglomerate or grit. Some bands are several inches thick. Sandstone beds with calcareous cement. Very fossiliferous at the top: *Stropheodonta* sp. ind. (r), *Anoplotheca flabellites* (a), *Uncinulus* sp. ind. (a), *Straelenia barrandii* (r), *Rensselaeria marylandica* (r), *Meristella lata* (c), *M.* sp. ind. (c), "*Spirifer*" *arenosus* (r), "*S.*" *murchisoni* (c).	13	18½
Limestone, dense, dark blue with lenses of bluish-black chert.	5½	5½
Concealed.		

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* These sections were originally measured by R. B. Rowe for the Maryland Geological Survey. (205, pp. 188-189.) Sections slightly modified by the writer.

North side of the bridge in abandoned quarries ⅛ mile east, a complete section through the Oriskany may be seen. This section was so accurately measured by Rowe that it is here repeated, with additional fossils obtained by the writer, and other minor details.

	Feet	
	Unit	Total
Onondaga group:		
Needmore shale:		
Black and gray shale, mostly covered. Massive coarse conglomerate with large pebbles.	½	65
Oriskany group:		
Ridgeley sandstone:		
Massive coarse conglomerate with large smoothly worn quartz pebbles; contains Oriskany fossils.	1½	64½
Massive light gray limestone with bands of grit or conglomerate near bottom. Conglomerate bands several inches thick consisting of small pebbles and coarse sand. *Pholidops multilamellosa* (c), *Lingulapholis terminalis* (rr), *Platyorthis planoconvexa* (rr), *Stropheodonta magnifica* (r), *Leptaena rhomboidalis* var. *ventricosa* (r), *Chonostrophia complanata* (rr), *Straelenia barrandii* var.? *fitchana* (r), *Rensselaeria marylandica* (c), *R. suessana* (c), *R. ovalis* (rr), *Meristella lata* (aa), *M. rostellata* (rr), *M.* sp. ind. (a), "*Spirifer*" *arenosus* (r), "*S.*" *murchisoni* (c), *Actinopteria textilis* var. *arenaria* (rr), *Platyceras gebhardi* (a), *P. nodosum* (r), *Diaphorostoma ventricosum* (rr) discovered.	12	63
Covered.	10	51
Light gray massive arenaceous limestone.	8	41
Covered.	2	33
Heavy dark gray limestone with conglomeratic bands at top. Bands 4 or 5 inches thick consisting of small quartz pebbles and coarse sand. *Diaphorostoma ventricosum* (rr) present.	10	31
Covered.	6	21
Conglomeratic dark gray limestones. Fine pebbles and coarse sand throughout this limestone.	3	15
Helderberg group:		
"Becraft" formation:		
Light gray massive limestone: "*Spirifer*" *concinnus* (aa), "*S.*" *cyclopterus?* (r), *Meristella arcuata* (c), *Schuchertella woolworthana* (rr).	12	12

Neelyton, Huntingdon County

The Neelyton section is in southeastern Huntingdon County on State Highway 433 on the southeast corner of an intersection with a dirt road to Burnt Cabins. This is the only complete section through the Oriskany in this area. The weathered and broken down condition of the strata make it rather unsatisfactory.

	Feet	
	Unit	Total
Onondaga group:		
Needmore shale:		
Thin-bedded shale, weathers yellowish green.		

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
Sandstone broken down into loose sand and sandstone blocks, weathers brownish; some chert, weathers white. Partly covered. Quartz grains 1/32 to 1/16 inch in diameter. "*Spirifer*" *murchisoni* (r).	57	166±
Shriver formation?		
Broken down impure chert, weathers buff; some punky chert. *Edriocrinus pocilliformis* (r), "*Spirifer*" *murchisoni* (r), "*S.*" *tribulis* (r), *Anoplotheca dichotoma* (c), *A.* cf. *fimbriata* (r), *Meristella* cf. *lata* (r).	30±	109±
Helderberg group:		
New Scotland formation?		
Concealed with much loose impure chert. Limestone, dense with interbeds of chert; black to bluish black. *Eospirifer macropleurus* (c), *Schuchertella woolworthana* (c) present.	79±	79±

Falling Springs, Perry County

The Falling Springs section is in a ditch on the west side of State Highway 850 along Sherman Creek 1.7 mile west of Dromgold on the new Bloomfield quadrangle. The Onondaga strata are exposed in a creek bed just south of a concrete bridge where Route 850 makes a sharp bend to the north; the Oriskany beds begin under the south side of the bridge.

	Feet	
	Unit	Total
Onondaga group:		
Selinsgrove limestone:		
Limestone, bluish-black, argillaceous, tough. In layers 8 to 12 inches thick with interbeds of black shale.	20	121±
Needmore shale, black, weathers gray: *Cranaena* cf. *romingeri* (r), *Pholidostrophia* sp. ind. (r), *Eodevonaria hemispherica* (c), *Strophalosia truncata* (c), *Anoplotheca acutiplicata* (c), *Odontocephalus selenurus* (c).	30	101±
Oriskany group:		
Ridgeley sandstone and chert:		
Sandstone and conglomerate, white, weathers buff. Pebbles chiefly quartz, well-rounded 1/16 to ⅛ inch in diameter. "*Spirifer*" *arenosus* (r), "*S.*" *murchisoni* (r), *Rensselaeria marylandica* (r) present.	31	71±
Chert, white arenaceous in upper part. Strongly weathered, partly concealed.	40±	40±
Helderberg group:		
Mendata shale and chert:		
Exact contact with the Oriskany not certain. Chert, weathers white to yellowish, blocky and in beds. *Eospirifer macropleurus* (c), "*Spirifer*" *perlamellosus* (c), *Eatonia medialis* (c), *E. singularis* (r).		

Schuylkill Haven, Schuylkill County

An Oriskany section is exposed about 1 mile east of Schuylkill Haven, in the Dalego limestone quarry, and just northeast of the Pennsylvania Railroad cut, uphill from the quarry.

	Feet Unit	Feet Total
Onondaga group:		
Needmore shale:		
Black calcareous fossiliferous shale.		
Oriskany group:		
Ridgeley sandstone:		
Concealed; blocks of conglomeratic sandstone common on hill slope between Needmore shale exposure and Ridgeley in top quarry. "*Spirifer*" *arenosus* fauna common in blocks.	40±	64±
Conglomeratic sandstones with pebbles up to ¼ inch in diameter, well rounded. Speckled in appearance, due to oxidation of iron minerals. Weathers brownish. "*Spirifer*" *arenosus* (c), "*S.*" *murchisoni* (a), *Rensselaeria marylandica* (a) found in east side of quarry at top.	4	24
Helderberg group:		
Light-greenish quartzite and apple-green calcareous shale. *Orbiculoidea* sp. ind. (r), *Chonetes* sp. ind. (c). Formational correlation unknown, possibly the equivalent of the New Scotland, Coeymans and upper Keyser.	14½	20
Keyser limestone		
Bluish-black medium-bedded limestone with interbeds of black shale: *Chonetes jerseyensis* (a), *Camarotoechia litchfieldensis* (r), *Stenochisma* cf. *deckerensis* (a).	5½	5⅓

Approximately 54 feet of this Keyser limestone are exposed in the quarry.

Little Gap, Carbon County

This section is in the southeastern corner of Carbon County, five miles east of Palmerton, and approximately ½ mile south of Little Gap Post Office. Aquashicola Creek flows south through the ridge at this locality. Stony Ridge is on the west side of the gap, Chestnut Ridge on the east. The section is on the west side of the State Highway in the end of Stony Ridge.

	Feet Unit	Feet Total
Onondaga group:		
Palmerton sandstone:		
Coarse-grained conglomeratic sandstone. Weathers buff, contains large cup corals.	120	235½±
Bowmanstown chert:		
Flaggy impure chert; weathers grey and buff. "*Spirifer*" *macrus* fauna.	54	115½±
Concealed.	10	61½
Medium-grained sandstone, weathers buff.	4	51½

	Feet	
	Unit	Total
Oriskany group:		
Ridgeley sandstone:		
Shale, red (iron-enriched)	1½±	47½
Coarse conglomeratic sandstone carrying *Stropheodonta magnifica* (r) "*Spirifer*" *arenosus* (r), "*S.*" sp. ind. (c), *Rensselaeria* cf. *marylandica* (c), *R.* cf. *ovoides* (r).	12	46
Fine-grained sandstone, weathers buff.	9	34
Fine-grained gray cross-bedded argillaceous sandstone.	25±	25
Concealed.		

Minisink Mills, Monroe County

The best Oriskany section in Monroe County is in the gap made by Brodhead Creek through Godfrey Ridge. It is on the east bank of the creek in the cut made by the New York, Susquehanna & Western Railroad. In this section a nearly complete sequence of strata from the Esopus down into the lower Helderberg occurs.

	Feet	
	Unit	Total
Onondaga group:		
Esopus shale:		
Bluish-black strongly sheared sandy shale, weathers ashen gray: *Anoplotheca acutiplicata* (r).		
Oriskany group:		
Ridgeley sandstone:		
Coarse-grained calcareous sandstone interbedded with siliceous limestone and bedded black chert. The fossils are plentiful but are poorly preserved. "*Spirifer*" *murchisoni* (a), *Schuchertella becraftensis* (r). Across the creek high up on the ridge where the strata are less strongly sheared, "*Spirifer*" *arenosus* fauna may be collected.	55-60	115-120±
Siliceous limestone, arenaceous and calcareous shale and interbeds of black chert and chert nodules. Shearing especially strong in the shaly beds. Absolute fossil identifications are not practicable, nevertheless a "*Spirifer*" *of the* "*S*" *murchisoni* type is abundant. The exact lower limit of these Oriskany strata is debatable.	60±	60±
Helderberg group:		
Port Ewen shale:		
Strongly sheared calcareous black shale. *Dalmanites* sp. ind. and ostracoda are plentiful. (See the previous chapter on the Helderberg for details).		

CHAPTER IV.

MIDDLE DEVONIAN, STROUDSBURGIAN STAGE*

GENERAL STATEMENTS

Historical data. The Middle Devonian has a long history in geologic research in Pennsylvania. The creation of the First Geological Survey, 1836, with the appointment of the first State Geologist, Henry D. Rogers, initiated comprehensive studies of our geology. When Rogers printed his First Annual Report in 1836, he listed among the major divisions the "olive slate and sandstone" which included our present-day Middle Devonian and marine Upper Devonian, that is, the non-red shales and sandstones above the Oriskany (171). In the Second Annual Report, 1838, Rogers (172) first recorded, in the Delaware Valley, the presence of Onondaga limestone. He placed it at the base of his "Formation VIII" whose top was drawn at the lowest red beds of the Catskill facies. Further refinement led in the Fourth Annual Report, to subdividing VIII (174). Rogers failed to distinguish the Onondaga in central Pennsylvania, including it, not unnaturally, in the "Cadent Lower (Marcellus) black slate" which he found over wide areas at the base of the "gray sandstone and olive slate," the still higher Devonian marine beds. In the "Geology of Pennsylvania," 1858, Rogers applied his unique nomenclature to the Middle Devonian and divided it into four units (177):

CADENT SHALES *(Hamilton Group of New York).*

CADENT LOWER BLACK SLATE *(Marcellus slate of New York).*

POST-MERIDIAN LIMESTONE *(Upper Helderberg or Corniferous limestone of New York).*

POST-MERIDIAN GRITS *(Caudi-Galli and Schoharie Grits of New York).*

Rogers included in his "CADENT SERIES" an "Upper Black Slate" member, our present-day Burket ("Genesee") shale, probable correlate of the Geneseo black shale of New York. On the other hand, he grouped under the heading "POST-MERIDIAN" the equivalents of the Onondaga ("Corniferous") and the Esopus ("Caudi-Galli"). In so doing he recognized a relationship which since has largely been overlooked or misinterpreted.

The Second Pennsylvania Survey under J. P. Lesley produced disappointingly little new on the Middle Devonian. Lesley abrogated the Rogersian Latin nomenclature, but retained the numerical designations, and introduced a terminology drawn chiefly from New York. The Middle Devonian has been divided:

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* The term Ulsterian stage in New York includes the Onondaga and Schoharie, but not the Esopus which is classed with the Oriskany. If here used it would embrace the Onondaga group which includes the so-called Esopus of eastern Pennsylvania. No Schoharie is recognized in the State. Such use being inapplicable, Stroudsburgian is introduced from Stroudsburg, Monroe County, where the group may be observed at its best, for eastern Pennsylvania.

ROGERS, 1858	LESLEY, 1892	WILLARD, 1936
CADENT SERIES (in part)	Formation VIIIc, Hamilton formation	Hamilton group
		Mahantango formation
	Formation VIIIb, Marcellus formation	Marcellus formation
POST-MERIDIAN	Formation VIIIa, Corniferous and **Onondaga** limestones	Onondaga formation
		Limestones and shales
	Formation VIIb, Caudigalli grit	Esopus shale

Rogers published little on applied paleontology; Lesley disdained to employ the science in stratigraphy. Sad were the errors of correlation which resulted. The Onondaga was badly confused except in I. C. White's work (228, 229, 230). Because of failure to recognize it, the base of the Middle Devonian was improperly defined over wide regions. Nor did the Second Survey clearly determine the upper limit of the Hamilton. White mistook Hamilton coral reefs for Tully (228, 229). Where the Tully was really present, it was missed or not distinguished from the Helderberg. Consequently, Middle and Upper Devonian series were confused and the ''Genesee'' sometimes was called Marcellus!

Since the termination of Lesley's survey, an occasional paper has dealt with the Middle Devonian. Prosser (161) in the east and Williams and Kindle (265) in central Pennsylvania helped correct some of I. C. White's mistakes, particularly concerning its upper limit. Kindle was the first to give us an accurate picture of the geographic distribution of the Onondaga fauna (127). Stose and Swartz (202) in describing the geology of the Pawpaw and Hancock quadrangles foreshadowed what was set forth a year later by the Maryland Survey in its volumes on the Devonian (143). Their data apply directly to south-central Pennsylvania and their interpretation of the Middle Devonian and the delineation by the Maryland Survey are basically adaptable in this report to our adjacent counties. Particularly is this true of the upper and lower limits which the Maryland Survey drew, the former at the base of the ''Genesee,'' the latter at the top of the Oriskany. Butts's ''Altoona Section'' of 1918 (22) is the first modern discussion of an essentially complete Middle Devonian sequence in central Pennsylvania.

Composition and limits. The term Hamilton group as used by me in more recent publications on the Devonian of Pennsylvania, included all strata between the Oriskany and Portage groups (254, 256). Because this usage makes the Hamilton equal to or synonymous with the Middle Devonian, the validity of such a definition must be questioned. Possibly, Hamilton group should be dropped altogether. The problem is still debatable. Either we must use it as synonymous with Middle Devonian, drop the term, restrict it to its earlier use as the Maryland Survey has done, to those beds between the Marcellus shale and the base of the Portage, or use it to include the Marcellus and later Middle Devonian formations (242). I introduced Mahantango formation for those beds of post-Marcellus, Middle Devonian age in central Pennsylvania which fail to resolve themselves into the Skaneateles, Ludlowville and Moscow formations. It is usually easier to expand the use of a term than to restrict it, especially such a term as Hamilton which has been variously applied in different localities for many years. If it is retained as a group term for the entire Middle Devonian, it should at least include in its scope everything that has ever been placed in the Hamilton except the Tully. Failing this, the Maryland name Romney might be adopted, with modifications. The name was used there for a "formation" composed of the Hamilton, Marcellus, and Onondaga "members." To adapt it to present usage in classifications, it should be elevated to the value of a group. Such usage is supported by the character of our Middle Devonian which is a closely-knit sequence. The fauna throughout is fairly consanguineous, but has definite facies. Except locally, the stratigraphic sequence suffers no diastematic interruption, the Onondaga grading into the Marcellus and the Marcellus into the Mahantango. However, the use of Romney has its drawbacks. I have discussed the advisability of its retention with both Prof. C. K. Swartz and Dr. G. Arthur Cooper (personal communications). Cooper agrees with me that the Romney does not necessarily embrace the whole of the Middle Devonian. It is my belief that the equivalent of part or all of the Moscow formation may be cut out by a disconformity in south-central Pennsylvania. Swartz advises against the continued use of Romney because of its synonymy with Middle Devonian. For these reasons I am disinclined to use Romney, even if redefined. It seems logical to drop any term synonymous with Middle Devonian as quite superfluous.

Hamilton may thus still be called a group including the representatives of the Moscow, Ludlowville, Skaneateles and Marcellus formations and their subdivisions. The designation, Mahantango formation, is retained for beds of the Hamilton group above the Marcellus formation in Pennsylvania, even where the equivalents of the Moscow, Ludlowville and Skaneateles formations of New York are more or less clearly recognized. It is essentially the same as the "Hamilton member" of the Romney of Maryland, though more inclusive. Originally, Cleaves and I (257) attempted to correlate the eastern Hamilton group with the New York sequence, Moscow, Ludlowville, Skaneateles and Marcellus formations. The term Mahantango was introduced in central Pennsylvania by me when I felt that there the post-Marcellus formations are obscure (242). In reviewing the problem in the field with Dr. Cooper in 1937, he advised dropping for lack of undoubted, direct correlations, the New York terms save for the Marcellus formation. For this reason I am retaining the others only as facies (chiefly faunal facies) of the Manantango. Consequently, throughout Pennsylvania the Hamilton group is divided into two formations, the Mahantango above, the Marcellus below, but these in turn are locally analyzed into lesser units or facies. My original description of the Mahantango formation follows (242):

> *Mahantango formation.*—The name, Mahantango formation, is introduced to include all beds between the upper Marcellus (Mahanoy) black shale and the base of the Portage. This is equivalent to the term, Hamilton, as formerly in general use. As the name, Hamilton, is now a group term, and because the post-Marcellus beds in central Pennsylvania are lithologically inseparable into formations, it is necessary to employ some new title for these strata. It is named for the North Branch of Mahantango Creek in whose valley and in adjacent parts of Snyder and Juniata counties, are excellent exposures. The Mahantango formation is exposed throughout central Pennsylvania except in a few sections in south-central Juniata County where erosion has cut down into the Marcellus. Its thickness varies from a maximum of 1,100 feet, in Northumberland County, to a minimum of only about 500 feet, in western Juniata; the average is 855 feet. With the exception of the prominent Montebello sandstone, to be described later, the Mahantango formation throughout is of nearly uniform lithology. It contains some rather heavy sandstone lenses in south-central Pennsylvania, but the dominant lithology is uniformly dark gray or brown, usually clayey or finely arenaceous shale to fine-grained, dark, shaly sandstone which may become platy or flaggy locally. There is little variation in the fresh rock other than these textural characters, but the weathered products differ considerably, producing sometimes small, polygonal chips, again pencil-shaped fragments, now large, irregular blocks, and occasionally thin, sandy plates. Spheroidal weathering is not uncommon in the more clayey shales, and is not always immediately distinguishable from the occasional storm roller bands. In general, these weathered materials are lighter colored than the fresh rock.
>
> Usually, the Mahantango shales are highly fossiliferous, although the faunules are specifically more limited than in New York, approximating the Maryland lists. Vast numbers of organisms are sometimes found, the commonest, *Spirifer mucronatus* and *Tropidoleptus carinatus*, with *Taonurus* sp. usually present. Other brachiopods, pelecypods, gastropods, bryozoans, and arthropods abound locally. With the application of paleontology it is possible to recognize, particularly in the eastern sections, faunal facies equivalent to the three formations of eastern Pennsylvania. West of the Juniata the faunules are less diversified, the formation is partly concealed, and continental beds supplant the marine in northeastern Fulton County. In southern Fulton County, fossils again become plentiful, but it is more difficult to distinguish the three faunal facies. Particularly is this true of the Skaneateles, for a number of fossils, most common to that formation, tend to reappear at intervals, particularly in stray sandstones, in the higher parts of the column.

By adopting the foregoing usage, the name Hamilton is retained and reverts to an earlier definition. A very real value is apparent from such a use, for, we are able to speak of the Hamilton fauna or of the Hamilton facies as contrasted with or distinguished from the older, but nearly related Middle Devonian. Of this, more appears in Chapter V.

The lower limit of the Middle Devonian in Pennsylvania is drawn at the top of the Oriskany group, that is, of its upper member, the Ridgeley sandstone. The lithologic change is always abrupt, a sandstone, often so coarse as to rate as a fine conglomerate, to one of the Onondaga shale members (Esopus or Needmore).[†] In the extreme eastern sections where the Esopus shale member of early Onondagan age is present, it rests in disconformity on the Oriskany coarse sandstone. Both Henry D. Rogers (177) and I. C. White (228) noted this disconformable relation. The Esopus belongs, not with the Oriskany, but for both physical and biologic reasons, with the Onondaga (251). Only 11 per cent. of the fossils known from the Onondaga in Pennsylvania have been recognized in the Oriskany or older Devonian beds of the State.

[†] Locally, an exception is found in the cherty and sandy Esopus units of the Lehigh Valley. The name Esopus is retained in this report, but it is appreciated that its precise correlation with the type Esopus of New York has not been proven (206).

The upper contact of the Middle Devonian varies somewhat in sharpness of definition. In 1935 I discussed this at length (247):

> Throughout nearly the entire region where the Middle-Upper Devonian contact is exposed, the top of the Hamilton Middle Devonian group is clearly defined. In many instances it carries a *Vitulina pustalosa* zone with or without *Spirifer tullius*, but usually the lithology and fauna of the overlying strata, because of their striking dissimilarity to the Hamilton, are the best evidence for locating the contact. The Tully limestone with characteristic fauna is known to rest directly upon the Hamilton all along the Allegheny Front between central Bedford County and eastern Lycoming County and again in a small area in southeastern Northumberland County. [It has since been found in Perry and Schuylkill counties as well.] The gray, massive or banded limestone furnishes a sharp lithologic break from the underlying clayey, dark gray, buff-weathering Hamilton shale. No truly transitional beds between the Hamilton and the Tully have been observed anywhere in the State. The faunal change is also distinct and significant. Eastward from the Allegheny Front where the Tully disappears, the Burket ("Genesee") shale succeeds the Hamilton. Again, a sharp lithologic difference is observed at the Middle-Upper Devonian contact. The same type of dark gray, clayey, non-fissile, upper Hamilton shale is overlain by the black, fissile, Burket shale. Again, no transitional phase has been recognized in Pennsylvania. Paleontologic differences are as distinctive as the lithologic dissimilarity. The upper Hamilton is usually quite fossiliferous with a characteristic fauna. The Burket, on the contrary, is customarily nearly barren save for *Buchiola retrostriata*, or allied forms, and the ubiquitous, but not particularly diagnostic, *Styliolina fissurella*. The Burket has been recognized as far east as the Lehigh River Valley near Lehighton. East of that it has not been found and is thought to have been displaced laterally by coarser, clastic sediments with an Ithaca fauna, the lower part of the Trimmers Rock [Portage] sandstone. [In 1937 it was found in western Monroe County.]
>
> Because of its eastward disappearance, the black shale no longer furnishes a means to separate the Middle from the Upper Devonian. Instead the Trimmers Rock sandstone rests directly upon the Hamilton in our most eastern sections. However, in Monroe County on Brodhead Creek north of Stroudsburg *Hypothyridina venustula* was discovered in a faunal zone in the base of the Trimmers Rock sandstone. The stratigraphic position and the fossils associated there warrant the correlation of this zone with the Laurens member of eastern New York. Such a correlation is substantiated by the fact that the *Hypothyridina*-bearing stratum occurs immediately above the topmost beds of the Hamilton with their characteristic fauna. This occurrence of mixed Tully and Ithaca organisms appears to be unique for eastern Pennsylvania. Consequently, east of Brodhead Creek, the Laurens fauna also fails as a means of identifying the basal Portage. Simultaneously, *Vitulina pustulosa* is no longer found at the top of the Hamilton. Prosser did not report it from Pike County, nor has the author found it east of Brodhead Creek. Both Hamilton and Portage groups in Pike County are dominated by sandstones of similar lithology, and their respective faunas are intimately mingled. Their relations are held to be transitional with no definite line of separation here between Middle and Upper Devonian.
>
> ....
>
> In reviewing the terminology of the Hamilton, Cooper points out that the inclusion of the Marcellus in the group, along with the Moscow, Ludlowville and Skaneateles, was adopted by Williams in 1890. This is the use finally accepted and applied with clearness and success by Cooper in New York. His statement of the case is quoted fully in Chapter V.

> Thus, from the Allegheny Front eastward across Pennsylvania, the lower limit of the Upper Devonian is drawn successively at the base of the Tully limestone, of the Burket black shale and of the Trimmers Rock sandstone with a Laurens faunule. Still farther east, none of these criteria remains, and transitional relations obtain between the Middle and Upper Devonian. This variation is attributed to the fact that the fine-textured, western members of the Portage group pass eastward into sandstones which supplant them by lateral displacement until only the coarser clastics remain. In southcentral Pennsylvania, a somewhat different story may be recounted. From central Bedford County southeastward into southern Fulton County, the top beds of the Hamilton are overlain successively by Tully, Burket, Harrell and Braillier [Brallier] members of the Portage. Here slightly different facies succeed one another more rapidly than in eastern Pennsylvania.

It may be added in supplement to the last statement in the above quotation that, since it was written, more intensive studies of the faunas of the upper part of the Mahantango formation have indicated that the highest beds corresponding to the Moscow formation in the east, are probably absent in southcentral counties. If so, there is a larger disconformity between the Middle and Upper Devonian in southcentral Pennsylvania than elsewhere in the State.

Distribution. The Middle Devonian enters Pennsylvania in the east along the Delaware River Valley. The higher beds, down to the Marcellus formation, cross the river in the vicinity of Matamoras, opposite Port Jervis, New York. The Marcellus shale floors much of the lowland bordering the river as it flows southwestward to Walpack Bend. At that point the stream makes a sharp turn toward the southeast so that the Marcellus, Onondaga and Esopus, and, for that matter, much or all of the Lower Devonian formations as well, cross over into Pennsylvania. From Walpack Bend, the Middle Devonian runs southwest in a relatively narrow band to the Schuylkill Valley. In western Monroe County and in the vicinity of Schuylkill Haven, it doubles back in broad S-curves and then resumes its former trend to the Susquehanna above Harrisburg, crossing that river at Rockville.

The closely folded Paleozoics of central Pennsylvania expose many bands of Middle Devonian beds. Emerging from under the Anthracite Fields along western Luzerne County and extending to meet the band already traced from the Delaware, additional Middle Devonian strata spread westward through the lower Susquehanna-Juniata valleys region and thence southwestward, chiefly in intermontane valleys, to enter Maryland from Fulton and southwestern Franklin counties. Throughout this entire region, the Middle Devonian is usually confined to long, narrow, zigzag lines.

An attenuated strip of Middle Devonian strata forms a great arc adjacent to and slightly east of the Allegheny Front from the Mason-Dixon line north, northeast and east through Lycoming County where it ties in with other areas in the Sunbury region. From the band along the "Front" outliers and spurs extend east in Bedford and Blair counties.

Throughout the entire region, most of the Middle Devonian is usually well-developed; but the lowest part, the Onondaga formation, is not always so well represented, and it appears to be nearly or quite absent in some sections, particularly in parts of the Susquehanna

Valley (251). Exposures of the Middle Devonian vary in excellency. Most of the region of its outcrop is south of the limits of Pleistocene glaciation, but in some areas drift hides the sections. Outwash conceals bedrock in certain of the river valleys. However, in general along the principal stream courses and in railroad and highway cuts the rocks of Middle Devonian age are well exposed.

Middle Devonian Sequences and Correlations

The following tabulations demonstrate the characteristic make-up of the Middle Devonian across Pennsylvania. Also, they illustrate the discussion of correlation in a succeeding section. These sequences range from the northeast to the southwest. Sections from adjoining States are introduced, first, for completeness, comparison and reference.

Sequence a

NEW YORK, (generalized after Cooper, (78, 79), Goldring (104), etc., and carried down to top of Oriskany. Certain local units, unknown in Pennsylvania, have been deleted.

Middle Devonian	
Moscow formation	
Windom member:	Shale, soft, gray; grows sandier and thickens eastward. "*Spirifer*" *tullius* and *Vitulina pustulosa* zone at top. Portland Point limestone at base
Ludlowville formation:	Not subdivided in eastern New York; uniform sandy shale with Hamilton facies. Coral beds in lower part. In western sections Deep Run, brittle bluish shale with large *Tropidoleptus* occurs with other members.
Centerfield member:	Thin, sandy limestone with many fossils, particularly corals, at base.
Skaneateles formation	
Colgate member:	Dark sandstone and shale, highly fossiliferous locally.
Berwyn member:	Shale, dark, sandy in central New York, sandier eastward; Hamilton facies. *Vitulina pustulosa* zone at base.
Pompey member:	Black shale passing upward into mudstone or cross-bedded sandstone.
Delphi member:	Shale, dark, soft to sandy; large pelecypods.
Mottville member:	Shale, soft to hard; hard crinoidal limestone in midst.
Marcellus formation	
Cardiff member:	Shale, gray; *Liorhynchus* fauna. Grows sandier eastward, taking on Hamilton facies; *Taonurus* plentiful.
Chittenango member:	Shale, jet black, fissile; large septaria; brown streak; *Styliolina* its only fossil. Cherry Valley limestone locally at base.
Union Springs member:	Alternate thin bands of black limestone, and sooty, black shale above Onondaga. *Styliolina* and a few other fossils known.
Onondaga formation	Rather pure, more or less cherty, massive to platy, blue limestone.
Schoharie grit:	Locally developed in eastern New York. Impure, siliceous limestone to buff, sandy beds; fossiliferous.

Esopus shale or grit: Locally developed in Hudson Valley. Dark gray, sandy shale; nearly barren.

Note: In extreme east, the upper Marcellus and later beds tend to be displaced by the Panther Mountain continental facies. All beds above the Onondaga are included by Cooper in the *Hamilton group*. The assignment of the Schoharie and Esopus is not necessarily final.

Sequence b

NEW JERSEY, Green Pond Mountain syncline, after Kümmel and Weller (130) and Weller (223), modified by Willard (254).

Upper and Middle Devonian
- Skunnemunk conglomerate: Thick, red, conglomeratic, continental facies; the upper part is Portage or later, the lower part is Middle Devonian in age.
- Hamilton group
  - Bellvale member: Thick, sandy shale to flagstones. Hamilton facies fauna. Probably entirely Marcellus in age.
- Onondaga group
  - Cornwall member: Shale, partially siliceous, argillaceous, dark, much sheared. Onondaga fauna.
  - Kanouse member: Heavy-bedded, fine, light-colored quartzite and conglomerate growing thinner-bedded upward. Onondaga fauna.

Sequence c

MARYLAND, Middle Devonian sequence according to the Maryland Survey, 1913 (143).

Middle Devonian
- Romney formation
  - Hamilton member
  - Marcellus member
  - Onondaga member

Sequence d

EASTERN PENNSYLVANIA, composite of Delaware, Lehigh and Schuylkill valleys, after Willard (254), and Willard and Cleaves (257).
Middle Devonian
- Hamilton group
  - Mahantango formation
    - Moscow facies, faunally like New York, lithologically vaguely defined. Clayey shale and fine sandstone; usually very fossiliferous; *Vitulina* common, with or without "*Spirifer*" *tullius*, at or near top.
    - Ludlowville facies, a succession of alternating gray, sandy shale and shale.
      - Centerfield coral zone, common at base, usually followed by a storm roller zone. Both die out westward, but the fauna of the reef may survive to the Susquehanna.
    - Skaneateles facies, in east: undifferentiated, dark gray, sandy shale. fossils scarce; westward: elements suggest the New York Berwyn with a *Vitulina* zone at base; Delphi, and questionable Mottville limestone lentil with crinoidal fragments.
      - Fort Hunter* sandstone, hard, fossiliferous at or near base; western sections only.

---

* Rockville was used by Willard and Cleaves but is preoccupied. Fort Hunter is about 4 miles north of Harrisburg.

Marcellus formation
  Brodhead member: "Cardiff †lithologic facies; dark to black, finely arenacoues shale, often highly fossiliferous; eastern sections only.
  Turkey Ridge member (?), fairly heavy, coarse, barren sandstone.
  Chittenango or Shamokin member (?), dark to black shale, sometimes concretionary, nearly barren.
  Union Springs member (?), black sooty shale, more or less limy; fossiliferous.
Onondaga group. The members listed below are partly complementary.
  Buttermilk Falls limestone, dark, charty limestone.
  Selinsgrove limestone, dark, non-cherty limestone.
  Hazard paint ore, limy band rich in iron carbonate.
  Esopus shale, dark, gritty shale; local chert and sandstone.‡
  Needmore shale, dark, limy shale.

Sequence e

LOWER SUSQUEHANNA VALLEY, southeastern Perry and west-central Dauphin counties, chiefly (257, 242).

Middle Devonian
  Hamilton group
    Mahantango formation
      Moscow facies
        Shales, buff to olive and fine, blocky sandstone beds. Very fossiliferous; *Vitulina pustulosa* zone at top.

      Ludlowville facies
        Dominated by the coarse Montebello sandstone facies. Highly fossiliferous.

        Deep Run member (?), dark shale with large *Tropidoleptus* in northern Perry County.

        Centerfield coral zone, probably present but poorly developed in northernmost quarry at Rockville on the Susquehanna.

      Skaneateles facies
        Dominated by the coarse Montebello sandstone facies. Quite fossiliferous. The recognition of Berwyn and Delphi members is made questionably upon the fauna.

        Fort Hunter member, sandstone, thin, very hard, dark, massive, brown-weathering, interbedded in shalier, lower part of Montebello facies. Fossils few.

Montebello sandstone facies. Sandstone, coarse, and conglomerate, highly fossiliferous. Supplants shaly post-Marcellus beds in lower Susquehanna and Juniata valleys.

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† The validity of the use of Cardiff is doubted as it has been applied in New York, Pennsylvania, and Maryland to formations of different ages. Inquiry elicited from Miss M. Grace Wilmarth the following interesting facts: (Letter of July 19, 1935)

"In January, 1904, the United States Geological Survey adopted, for use in folios covering areas in the Piedmont Plateau of southern Pennsylvania and northern Maryland, the name *Cardiff quartzite,* for rocks at that time believed to be of Silurian age. In February, 1904, (Am. Jour. Sci., vol. 17, p. 143) Dr. E. B. Mathews published this name as *Cardiff conglomerate,* and tentatively assigned it to Ordovician (?). (The preseut approved name is *Cardiff conglomerate* and the approved age designation is *pre-Cambrian.*)"

"In June, 1904, (N. Y. State Mus. Bull 63, p. 16) Clarke and Luther introduced the name *Cardiff shale* for 50 to 100 feet of beds forming the top member of the Middle Devonian Marcellus shale (as generally applied in New York) in the Canadaigua and Naples quadrangles of that State."

‡ The Esopus in the Lehigh Valley includes the Palmerton ss and Bowmanstown chert (206).

Marcellus formation

Only partly present as black shale of Chittenango type and correlated with the Mahanoy member of central Pennsylvania (see sequence f below).

Onondaga group

Absent

Sequence f.

SUSQUEHANNA-JUNIATA VALLEYS embraced chiefly in Juniata, Snyder, and southern Northumberland counties (232, 242).

Middle Devonian

Hamilton group

Mahantango formation

Shale, dark gray to brownish, often clayey or finely arenaceous; occasional sandstone lenses may become moderately prominent west of the Juniata. Usually highly fossiliferous, the fauna divisible into approximate equivalents of the Moscow, Ludlowville and Skaneateles facies of eastern Pennsylvania; a *Vitulina pustulosa* zone common at top. The lower part may be displaced by the Montebello sandstone facies (*cf.* sequence e).

Marcellus formation

Mahanoy member: Shale, fissile, black, nearly barren.

Mexico member: Sandstone, fine, light-gray to whitish, platy, weathers brown along bedding surfaces. Usually barren.

Turkey Ridge member: Sandstone, platy to massive, rather coarse, hard, olive-gray, barren.

Shamokin member: Shale, fissile, black, nearly barren, identical to Mahanoy member in appearance and inseparable therefrom where Mexico and Turkey Ridge members are absent toward the north. Basal beds sometimes suggest Union Springs sooty shale.

Onondaga group

Selinsgrove limestone: Limestone, dark gray, weathers light gray, usually chert-free, platy, but occasionally massive; fossiliferous.

Needmore shale: Shale, limy; thin limestone beds, lenses or nodules common. Dark gray when fresh. Weathers olive-drab; fossiliferous.

Sequence g.

SOUTH-CENTRAL PENNSYLVANIA, Fulton and Bedford counties. Middle Devonian (242, 246).

Hamilton group

Mahantango formations: Dominantly dark shale with thin local sandstones. Fossiliferous; Ludlowville and Skaneateles elements recognized, but Moscow probably absent. In southern Bedford County subdivided into:

Frame member: Shale, gray to olive, sandy with local sandstone and thin limestone lenses. Very fossiliferous.

Chaneysville member: Sandstone, hard, olive-gray, brown-weathering, platy to sub-massive. Fossiliferous.

Gander Run member: Shale, dark gray, brown-weathering, sandy. Fossiliferous.

In northern Fulton County, the Knobbsville continental beds occur. Here the Mahantango formation is largely supplanted by non-marine red and green beds.

Marcellus formation
Shale, black, fissile, sand-free, often weathering to light-colored, almost white chips. Limy nodules occur which, northward, become more common and coalesce into definite limestone beds in Huntingdon County. Fossiliferous.
Onondaga group
Selinsgrove limestone: Limestone, soft, dark gray, platy to shaly; fossiliferous. Often too shaly to be distinguished from the Needmore member below.
Needmore shale: Shale, limy with thin limestone beds, lenses or nodules, weathers olive-drab but dark gray when fresh. In western Mifflin County a thick, black shale, the Beaver Dam member, occurs near the middle. Fossiliferous.

The foregoing sequences are intended to supplement through regional details the much more comprehensive view of the Middle Devonian presented diagrammatically in Figures 40 and 93. By citing these few selected sections, a generalized concept is obtained of the Middle Devonian sequence in various localities where its development is particularly striking or significant. They and the tables should be consulted during further descriptions and correlations Be it repeated that, in all Pennsylvania sequences, it is understood that the post-Onondaga beds are assigned to the Hamilton group.

Onondaga Group Defined

In 1839 James Hall used the name Onondaga limestone to supplement the earlier, local appellations, Corniferous and Seneca, then in vogue in New York (109). Fifty-five years later N. H. Darton (81) proposed the name Esopus for a somewhat older shale then commonly called by the non-geographic name, "*Caudi-galli* grit." A second shale, the Schoharie, intervening between the Onondaga and Esopus, is recognized in New York, but is unrecorded in New Jersey or at the surface in Pennsylvania. Equivalents of the Onondaga limestone and Esopus shale are both believed to occur at the surface in Pennsylvania. In 1838, a year before Hall named the Onondaga, Rogers reported, but failed to name, this limestone in Pennsylvania (172). This was the first official recognition of the formation in the State. Rogers's fuller account of 1858 (177) designated it as the "Post-meridian limestone;" the Esopus he called the "Post-meridian grits." This early association of these two under the single heading, "Post-meridian," is significant in that it shows that Rogers apappreciated their close relationship. He mapped them from the Walpack Bend west to the Lehigh where he supposed they wedged out, nor did he recognize them as such elsewhere in Pennsylvania. The Second Pennsylvania Survey said much, did little about the Onondaga limestone and the Esopus shale. They were best handled in the writings of I. C. White whose first description of them appeared because of work in Pike and Monroe Counties (228). Here he found no Schoharie shale, observed the transitional upper and lower contacts of the limestone and the sharp break between the

Esopus shale and the subjacent Oriskany sandstone. B. L. Miller (146) has recently added details to the earlier studies by Hill (123) of the Onondaga in the Lehigh Valley. White again came to the fore when he described the Middle Devonian in the region of the Forks of the Susquehanna (229). He observed near Selinsgrove Junction a limestone and shale between the Marcellus and Oriskany and suggested their correlation with the Onondaga limestone and Esopus shale, respectively, as known in Monroe County. Other workers of the Second Survey were less fortunate in their interpretations. In Perry County, Claypole (72) failed to differentiate the distinctive and abundant Onondaga fauna and grouped the limestone as basal Marcellus. D'Invilliers (82) merely followed White's Selinsgrove designations, projecting them across the Susquehanna to the Juniata valley. Workers along the Allegheny Front and in southcentral Pennsylvania usually failed to find the Onondaga. Chance's reported Onondaga near Lock Haven is probably the Tully (56). Once more I. C. White rose above his colleagues when, in Huntingdon County, he was able to apply his Selinsgrove succession and identify the Onondaga there (230). Lesley summarized all of the views in his final report (137).

During the twentieth century, a few contributions have appeared. I have already cited the work by Stose and Swartz in the Pawpaw-Hancock folio (202) and its foreshadowing the Maryland Survey's subsequent Devonian interpretations (143). Mention also has been made of Butts's observations near Altoona where he found 50 feet of Onondaga limestone and shale (22). Kindle (127) in 1912 gave us by far the most comprehensive report to date upon the Onondaga. The geographic scope of his work, New York to Virginia, was so wide that comparatively few details could be listed for Pennsylvania. Cleaves and I casually mentioned the Onondaga in connection with our publications on the "Hamilton group in Pennsylvania" (257, 242, 246). In 1936 I summarized and published all the data which I had then amassed on the Onondaga, including the Esopus (251). The present discussion is drawn almost without modification (251) from that publication. Since my paper appeared, Swartz and Swartz (206) have added new data on the Esopus of the Lehigh Valley. It will be observed, that I now handle the Onondaga as a group separated from the Hamilton.

The Onondaga group in Pennsylvania is defined to include all stratigraphic units between the top of the preceding Oriskany group and the succeeding Marcellus formation of the Hamilton group. The Onondaga is faunally and lithologically possessed of close Hamilton affinities. It was because of these close relations, that I recently suggested the grouping of the Onondaga formation with the rest of the Middle Devonian as the "Hamilton group" (254). This grouping, though based upon good evidence, has been dropped for reasons explained in the next chaper. In Pennsylvania we find that the Onondaga group almost invariably consists of two formations of different facies, a limestone above and a shale below. Only in the south does the upper member lose identify These facies may be assigned formational rank and in themselves contain local units of minor importance.

Distribution

The Onondaga has a wide distribution from the Delaware Valley west and southwest to Maryland. It is somewhat more restricted than the rest of the Middle Devonian. The sketch map, figure 30, shows the regions of its outcrop. In parts of Fulton County Faulting has cut out the Onondaga. The group does not appear to be everywhere continous across Columbia and Montour counties, although to the east there is a good exposure at Beach Haven in west-central Luzerne County. I have not identified the Onondaga in Clinton County; and have seen it but doubtfully represented in Centre. Here, however, glacial drift or outwash deposits greatly hamper observations of the consolidated sediments, particularly those which are readily weathered or fail to form physiographic features. South of the glaciated region in westcentral Dauphin and southeastern Perry counties, the Onondaga is absent (*Cf.* County Maps, 154).

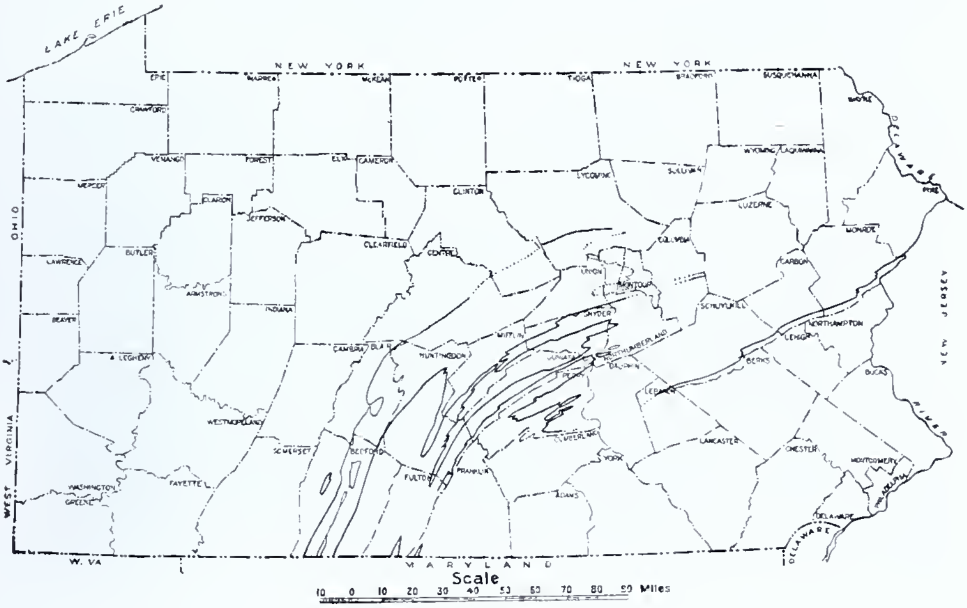

Figure 30. **Sketch map showing distribution of Onondaga group in Pennsylvania.**

Divisions of the Onondaga

The Onondaga group in Pennsylvania is divisible into several units, usually lithologically distinct but so closely allied faunally and intergrading one with another so imperceptibly that they perforce are treated as a single group. To the more important of these divisions, geographic names are now applied, partly for the first time. Such names have been under consideration for some years; in fact, it was debated when I published my Onondaga paper (251), whether they should be introduced then. They were not brought forward because of some uncertainty as to what policy of nomenclature eventually to use. In that paper the various parts of thė Onondaga group, except the already-named Esopus, were simply referred to by adjectives suggestive of their distinctive lithologies. Such a terminology is both cumbersome and vague. While I do not condone with those who would introduce a multiplicity of geographic names, I am so far in accord with present nomenclatorial trends that I am not averse to using new names for members and even lesser units when such names clarify the correlations or help eliminate unwieldly circumlocutions. Therefore, the Onondaga group has been subdivided. The distinctions are lithologic; the resemblances biologic.

TABLE XVIII

Central Pennsylvania	*Eastern Pennsylvania*
Onondaga group	Onondaga group
Selinsgrove limestone*	Buttermilk Falls limestone
Needmore shale†	Esopus shale‡

Buttermilk Falls limestone. This limestone is named for Buttermilk Falls, a handsome cataract, on Marshall Creek, Monroe County. I formerly called it ''upper member, cherty limestone (251). It has its most characteristic development in Monroe County. The limestone continues east into Pike, but west only into Carbon County. This limestone is, therefore, confined to eastern Pennsylvania. In Monroe County it reaches a maximum of about 200 feet and thins rapidly westward to only 5 feet on the Lehigh River above Palmerton. The Buttermilk Falls limestone most nearly resembles the Onondaga limestone of eastern New York. It is a massive, dark- or blue-gray rock replete with chert occurring usually as dark bands or nodules 2 to 3 inches thick up to larger chunks as much as a foot in diameter. Usually these are rather lenticular and appear to have their major axes approximately parallel to the bedding, in which position they sometimes coalesce into nearly continuous beds. Probably there is everywhere some chert in the Buttermilk Falls limestone, but the material appears to be most abundant in the middle 50 to 100 feet, while the highest and lowest parts are sometimes nearly chert-free. The beds poor in chert have a tendency to shear strongly, a character which is highly developed in the underlying Esopus shale. The Buttermilk Falls limestone is well exposed in southern Monroe County in numerous abandoned quarries, on highways and particularly along the Delaware, Lackawanna and Western Railroad south of East Stroudsburg where the relations between it and the Esopus are well illustrated. Other good sections may be observed along Brodhead Creek, particularly on the Erie (formerly the New York, Susquehanna and Western) Railroad, cuts on which expose the beds along the north flank of Godfrey Ridge.

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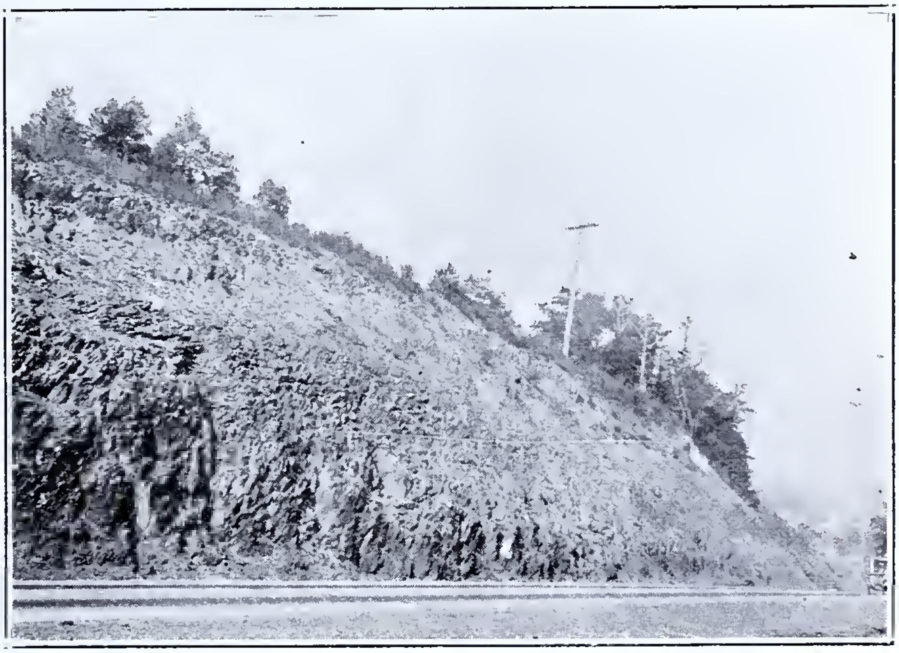
* I. C. White applied Selinsgrove to 5 members of the Middle Devonian (229). It is here proposed to drop it for all save one, his distinctive "Selinsgrove lower limestone" with the adjective "lower" now omitted.

† Called "Selinsgrove shale" by I. C. White (229).

‡ This is the Esopus or "Caudi-galli" of authors. Probably the use of Esopus is applicable, but until it is definitely traced through from the Hudson to the Delaware, the term is to be used with caution. A new name may be required here eventually, but rather than introduce one which may soon be discarded, Esopus is continued for the present until its final standing can be established.

These sections shown the passage downward into the Esopus, and the transition between the limestone, and the overlying Marcellus may be studied at Stroudsburg. Though the limestone makes small hogbacks in eastern Monroe County, as a rule despite the chert, it is no ridge-maker, but with the Marcellus, underlies valleys.

The strongly Middle Devonian fauna includes species distinctive of the Onondaga. Corals are quite numerous in the Buttermilk Falls beds in eastern Pennsylvania, but because of the abundance of chert, collecting is difficult, particularly in the median portions of the limestone. A further discussion of the fauna will be found below. (Also, see Table XXII.)



Photograph by Bradford Willard

Figure 31. **Esopus shale exposed on U. S. Route 611, south of Stroudsburg, Monroe County. Note shearing perpendicular to nearly horizontal bedding.**

Esopus shale. In discussing the Onondaga in 1936 (251), I adhered to the prevailing terminology, and this policy is not yet abandoned as implied in the third footnote of Table XVIII, page 144. The characteristic Esopus is the lower, shale formation of the Onondaga group in the eastern part of the State. Upon evidence which will be recited in due course, it is included with Onondaga rather than with the Oriskany. It enters Pennsylvania at Walpack Bend, the eastern extremity of Monroe County, and has a distribution similar to the overlying Buttermilk Falls limestone. It is best developed in Monroe County where it is over 300 feet thick, but it thins to approximately 260 feet in the Lehigh Valley near Palmerton, and to about 150 feet in Schuylkill County father west. In the Lehigh Valley both chert and sandstone occur in the Esopus. Otherwise its lithology is characteristically distinctive dark, ashen-colored or brownish, gnarly, sandy shale. Some beds are limy, particularly in the upper part where it grades into the Buttermilk Falls limestone. The rock has a peculiar tendency to shear strongly. The Esopus is well exposed in the vicinity of the Stroudsburgs. A splendid section is had across Godfrey Ridge on the new highway (U. S. Route 611) through Foxtown Gap. The railroads which follow the banks of Brodhead Creek also afford good cuts in the rock, as for example near the hydro-electric plant southeast of East Stroudsburg. The structure of Godfrey Ridge is complex, but the relation of the Esopus to the underlying coarse to pebbly Oriskany sandstone full of characteristic fossils is simple. The Oriskany terminates abruptly at the basal Esopus of characteristic lithology. The Esopus shale is probably barren in its lower parts save for an occasional *Taonurus*. This fossil is perhaps more common in the member than recorded, because intense shearing tends to obliterate it. It seems superfluous to observe that the Esopus took its old name, "*Caudi-galli*" grit, from the facied resemblance of these plumulous markings to the tail of the cock. The fossil is not confined in Pennsylvania to the Esopus, but is found in other Middle Devonian formations. Other fossils are sparingly present, chiefly in the highest beds. So far as identified, they are indistinguishable from species found in other parts of the Onondaga. Because the Esopus shale is closely allied with the Buttermilk Falls limestone and, conversely, distinctly set off from the Oriskany, it is included in the Onondaga groups. It should be reiterated that this is the stand which was taken by Henry D. Rogers (177) and I. C. White (228). Later, dissenting opinions seem to have placed the shale with the Oriskany because of the physiographic features which they jointly underlie, rather than because of lithologic or paleontologic similarities.

Selinsgrove limestone. In previously discussing the Onondaga group, I called the superior part in central Pennsylvania the "upper member, non-cherty limestone." Adapting I. C. White's term drawn from the region of Selinsgrove Junction on the east bank of the Susquehanna below Sunbury, it becomes the Selinsgrove limestone of formational rank.* There, today, the member may be studied in highway cuts and along the railroad. This limestone is recognized farther east to Carbon County where some 20 feet of "hydraulic cement rock" has been recorded on the Lehigh. West of the type locality, it is the characteristic upper member of the Onondaga group and is the analogue of the Buttermilk Falls member in the east. The absence of chert from the Selinsgrove is its chief distinction from the other limestone. It is usually dark gray to nearly black, rather soft and tends to be thin-bedded or shaly; but some heavy beds show at Selinsgrove Junction. On weathering, the thinner-bedded or argillaceous rock leaches to shaly, greenish to olive-drab, punky material so closely resembling the underlying Needmore shale as to be hardly distinguishable therefrom, especially where the shale is weathered and carries limestone bands and lenses. At Selinsgrove Junction there is 65 feet of this limestone, probably its maximum thickness. Southeastward it drops to 7 feet in Lebanon County, rises to 20 in Carbon, and, still farther east, appears to merge with the Buttermilk Falls member. Southwest and west of Northumberland County, the Selinsgrove limestone is widespread. It is 35 to 40 feet thick in central Perry County, and about 30 in northern Bedford County. Father south into Maryland, it is not known, but apparently changes laterally into the upper part of the Needmore shale which makes up the entire Onondaga along our southcentral border. The limestone has been observed in Mifflin County, but may be absent from Clinton and Centre counties. In Lycoming County on the highway east and west from Jersey Shore are exposures of the Selinsgrove limestone.

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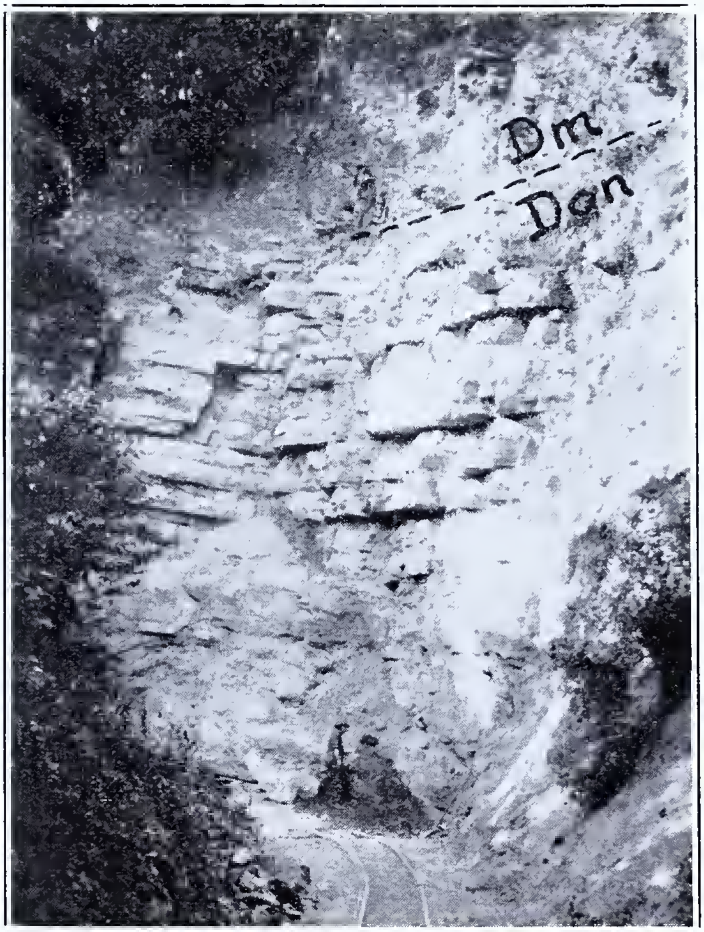
* Selinsgrove limestone is retained today by the West Virginia Geological Survey for a limestone of Onondaga age (160).

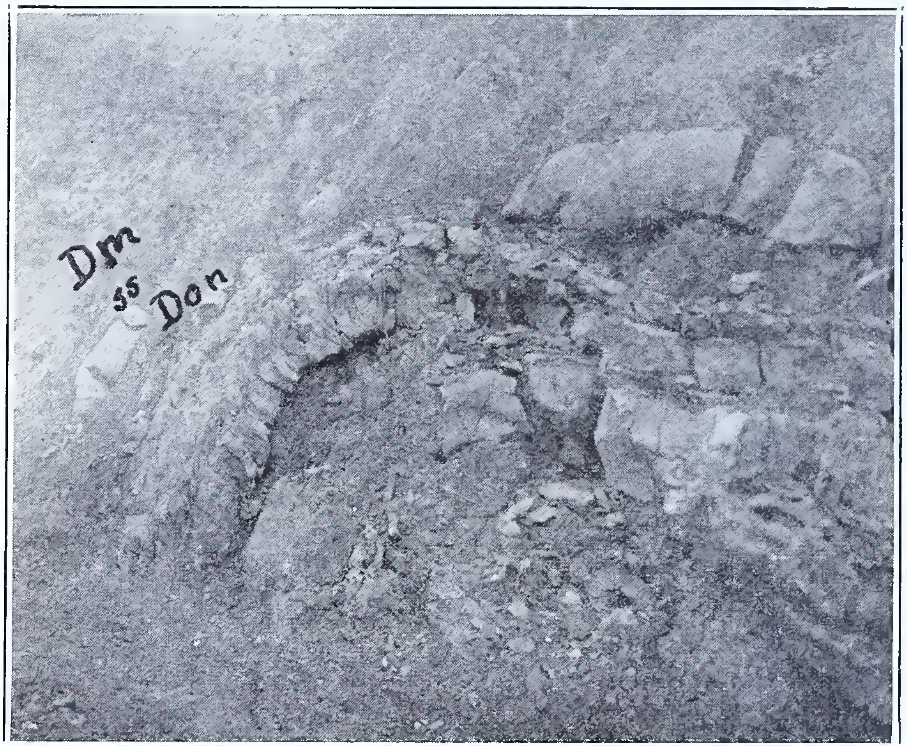


Photograph by George H. Ashley

Figure 32. **Old limestone quarry, east bank of Juniata River at Half Falls Mountain, Perry County. Selinsgrove limestone (Don) overlain, at top of quarry, by Marcellus black shale (Dm).**

Throughout, the Selinsgrove limestone usually abounds with a diversified Onondaga fauna rich in Hamilton species. Corals are rare in central Pennsylvania, a feature distinctly different from the Buttermilk Falls member.

Everywhere, so far as known, the Selinsgrove limestone and underlying Needmore shale of the Onondaga group are inter-transitional. The relations of the limestone to the Marcellus are not so constant. Generally, this contact is gradational, suggesting the relations between the Buttermilk Falls and Marcellus in the east. In the middle Susquehanna and lower Juniata valleys, the relations are disconformable. In southeastern Perry County and adjacent parts of Dauphin, the Marcellus appears to rest upon the Bloomsburg (Silurian) red beds. The exact contact is hidden today, though I infer from Rogers's writings that, long ago, he may have seen it in Perry County at exposures now buried (177). Whether this contact be a fault or of non-depositional origin is uncertain. This absence of the Onondaga, the Lower Devonian, and the highest Silurian may be due to local erosion, which is supplemented by subsequent faulting. Throughout the region west and southwest of Perry County, the limestone may stop abruptly at a lean iron ore at the base of the Marcellus. At Half Falls Mountain in Perry County and northward along the Juniata at Thompsontown and in southeastern Snyder County, the top of the limestone ends sharply. Its upper surface may be low, rounded bosses suggesting weathering. Upon this rests 1 to 16 inches of friable, brown, miraceous, ferruginous sandstone which intergrades with the Marcellus black shale above.



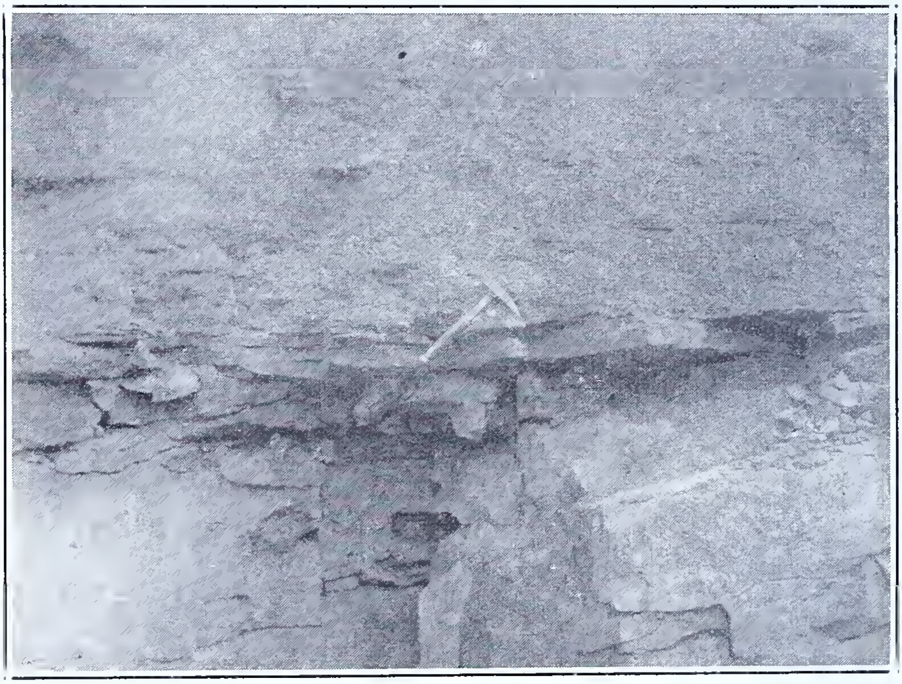
Photograph by Bradford Willard

Figure 33. **Anticline on Delaware Creek north of Thompsontown, Juniata County. The Selinsgrove limestone (Don) overlain by Marcellus black shale (Dm), thin sandstone (ss) separating them.**

The Selinsgrove limestone disappears locally east of Northumberland County. Though exposed at the Montour-Columbia County line between the Marcellus and Oriskany on a secondary road south from U. S. Route 11, it is more often absent. In certain localities it may be represented by a little residual red clay. On Big Fishing Creek above Bloomsburg, Columia County, the Tonoloway (Silurian) limestone is faulted against the Marcellus; the intervening formations are missing. Farther down stream, what is taken to be the top of the New Scotland member of the Helderberg group is overlain by some coarse sandstone probably of Oriskany age, and this is topped by the black Marcellus shale with no sign of Onondaga between. White (229) believed that the Oriskany pinched out east of Big Fishing Creek. He appears to have been partly correct. A like statement may apply to the Onondaga. In Luzerne County, however, just east of the Columbia County line near Beach Haven, the Selinsgrove limestone shows on the highway and along the Delaware, Lackawanna and Western Railroad. It has been questionably identified in the river bed at Berwick during low water. Evidently, in part of central Pennsylvania, it is not uncommon to find the Marcellus-Onondaga contact disconformable. The Onondaga at times is even unrecorded.

Needmore shale. Beneath the Selinsgrove limestone and supplanting it southward is a limy shale which I designated in my former discussion of the Onondaga as the "lower member, limy shale" It is here dubbed the Needmore for its exposures in southern Fulton County between Needmore and Warfordsburg. It is simply the downward continuation of the non-cherty limestone, the Selinsgrove member, and is distinguished therefrom solely upon the greater proportion of argillaceous material and, *pari parsu,* the decrease in limestone content. Dark to medium gray, it has occasionally been described as "green shale." This appears to be a misnomer. Strictly speaking, the greenish or olive to olive-drab hue develops only with deep weathering. Limestone is nearly always encountered in the Needmore shale as thin beds and lenses or nodules which grow more plentiful toward the upper part until they may dominate as the Selinsgrove limestone. Sandy beds appear in the Needmore in central Pennsylvania and are thought to increase slightly where the Onondaga finally disappears southwestward beneath the Allegheny Front. Even the limestone beds carry some sand grains. In the lower part of the Needmore, at least, they are probably derived from the Oriskany. In southern sections the Needmore member is 100 to 150 feet thick, and it maintains this thickness throughout most of the region west of the Susquehanna. It is 140 feet thick in the Selinsgrove Junction region, thins southward into Perry and is unknown above Harrisburg at the water gap. It may be present in Centre and Clinton and is known in Blair and Lycoming counties. East of Northumberland County, it thins just as the overlying Selinsgrove does. Throughout the Devonian areas in Snyder, Union and Mifflin counties, this shale is commonly exposed, and at Newton Hamilton in Mifflin County, there is an exceptional section which, because of its unique character, deserves the detailed description given below.

The top of the Needmore shale grades into the Selinsgrove limestone in all section where their contact has been seen. Where the limestone is absent, as in southern sections, the shale passes gradually over into the black, non-limy, fissile Marcellus shale. Such a contact is beautifully illustrated on U. S. Highway 522 north of Warfordsburg in Fulton County. The lower contact of the shale with the Oriskany is disconformable. Oriskany strata in southern and central Pennsylvania commonly terminate in weak, friable, coarse sandstone with a characteristic fauna. At some localities as at the cemetery at New Bloomfield, Perry County, and in northern Fulton County on the road between Hustontown and Fort Littleton, the Oriskany ends in a limonitic band. This ferruginous deposit may have originated through enrichment during an Oriskany-Onondaga interval of non-deposition and subaerial exposure. In western Mifflin County along the Pennsylvania Railroad east of Newton Hamilton, the basal contact of the Onondaga is remarkably distinct. The Needmore limy shale is thick in this section, and a thin limestone bed at its base rests upon the uneven top of the Oriskany. This limestone contains grains of Oriskany sand. (Figure 34.)



Photograph by Bradford Willard

Figure 34. **Contact of the Onondaga with the underlying Oriskany on Pennsylvania Railroad near Newton Hamilton, Mifflin County. Hammer marks contact at shaly, basal Onondaga.**

The Needmore shale is highly fossiliferous, more so than the other members of our Onondaga group. The fauna is clearly Middle Devonian with diagnostic Onondaga forms. The assemblage is in striking contrast with the Oriskany. The entire fauna is tabulated below, Table XXII.

Minor Onondaga variants. A few local variations of the Onondaga group in Pennsylvania are of sufficient importance to deserve special mention. We may disregard iron ores reported from the formation as these in every case appear to belong to either the Oriskany or Marcellus. The Schoharie shale (''grit'') of New York has not been recognized at the surface. Fettke (91) reported it in deep drilling in northeastern Pennsylvania, but the identification seems dubious. In the Lehigh Valley in the region of Bowmanstown, paint ore has been dug from the Onondaga for the better part of a century. This bed is often referred to as the ''paint ore near Palmerton,'' and is conveniently designated as the Hazard paint ore, by B. L. Miller, who described it (146):

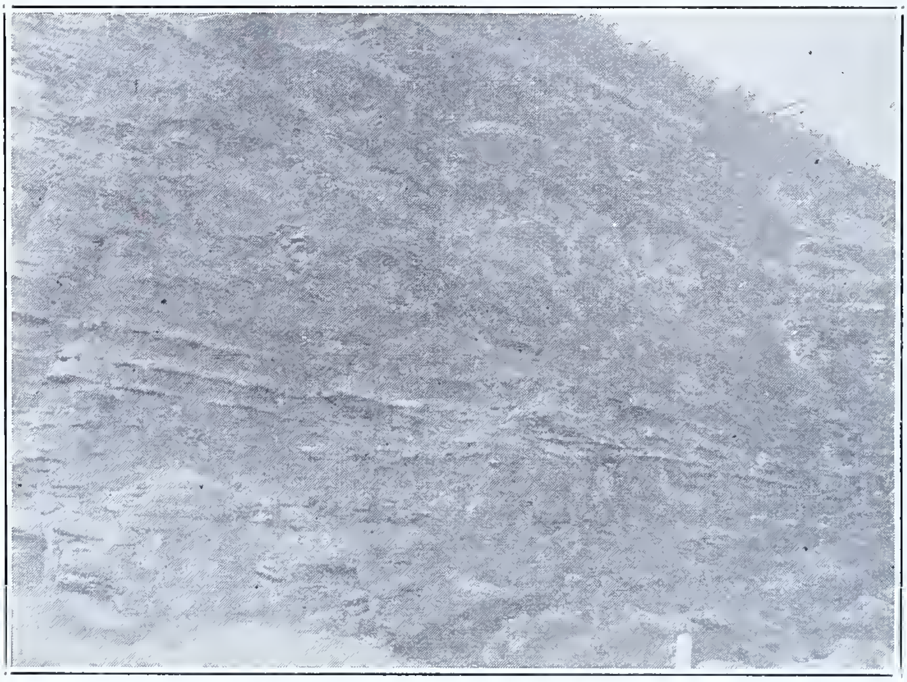
''The ore resembles impure blue limestone, but without distinct bedding or joint planes and were it not for the high specific gravity, it would scarcely be thought to possess any value. It is dark blue in color when fresh, but on being exposed to the air soon reddens due to the oxidation of the iron originally present in the form of the carbonate.''

Specimens examined effervesce in dilute hydrochloric acid. The ore is replete with an unmistakable Onondaga fauna. Miller listed fossils, but did not attempt a complete study of the fauna as his investigation of the ore was strictly economic. In coöperation with Dr. Lawrence Whitcomb, I have been enabled to study the collection of Hazard paint ore fossils belonging to the Department of Geology at Lehigh University (259). This fauna, listed below, Table XXII, is distinguished from other Onondaga faunas in the State by its low percentage of mollusks and unusually high number of trilobites, often finely preserved. The succession of the Onondaga on the Lehigh including the paint ore is:

Table XIX.

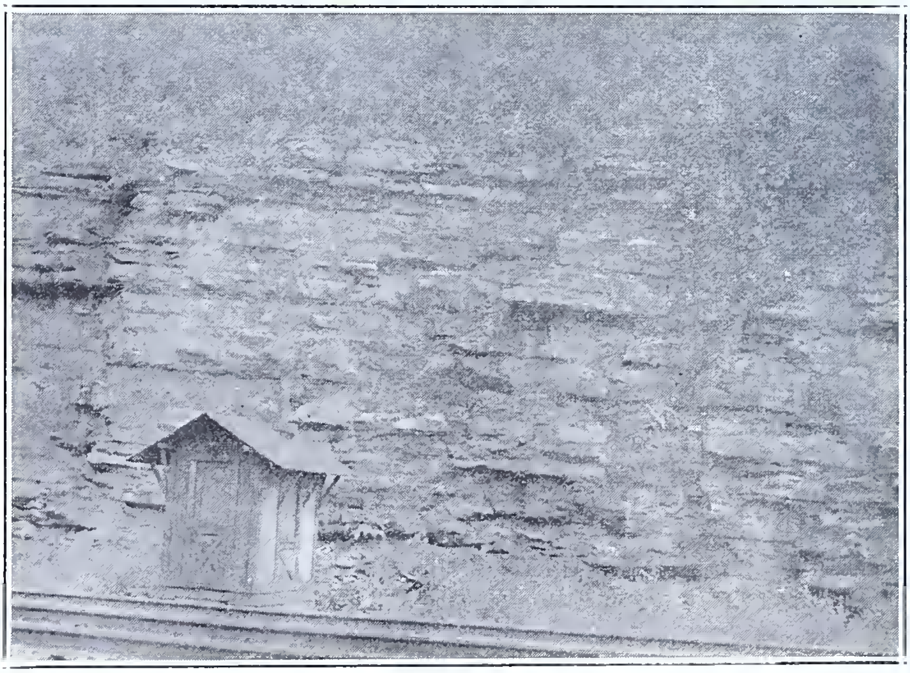
Hamilton group	
Onondaga group	Feet
Buttermilk Falls limestone	5
Selinsgrove limestone	20
Hazard paint ore	2–4
Esopus shale	87
Palmerton sandstone	120
Bowmanstown chert	54
Oriskany group	

The paint ore intergrades with the overlying limestone, but is sharply separable from the Esopus, a unique disconformity. At the same time, representations of both the Buttermilk Falls and Selinsgrove limestones are interpreted as present in the same section, a phenomenon not recognized elsewhere. The Esopus shale itself is identified by the presence of *Taonurus.* Presumably the post-Esopus intervals may partly include the missing Needmore shale of the west unless that shale be directly correlated with the paint ore as well as the Esopus.



Photograph by Bradford Willard

Figure 35A. Onondaga shale and limestone in cut on Pennsylvania Railroad near Newton Hamilton, Mifflin County. The illustration shows the black shale occurring here in the midst of the limestone.



Photograph by Bradford Willard

B. Onondaga limestone in cut on Pennsylvania Railroad near Newton Hamilton, Mifflin County. The photograph illustrates the intergradation of the limestone and included black shale of the Onondaga group.

Below the Esopus shale but above the true Oriskany (Ridgely) sandstone with characteristic fauna, are two members formerly supposed to be Oriskany, but shown recently by Swartz and Swartz (206) to belong with the Onondaga group. The upper of these they have called the Palmerton sandstone. It is about 120 feet thick and appears to be barren. Lithologically, it is coarse and Oriskany-like. Beneath it is 54 feet (measured by Cleaves, personal communication) of cherty material, the Bowmansville chert. Swartz and Swartz report such Onondaga fossils from it is *"Spirifer" marcus, "S." duodenarius, Amphigenia* cf. *elongata, "Chonetes" arcuatus, Leptocoelia (Anoplotheca) acutiplicata* and *Schuchertella pandora.* These exceptional Esopus conditions seem not to have continued west to the region of Schuylkill Haven where no sandstone was found between the Oriskany sandstone and conglomerate and the Selinsgrove limestone.

Another variant of the Onondaga is found in western Mifflin County and elsewhere in Lycoming County as at Jersey Shore. This is a black shale in the midst of the Needmore. Its type section is east of Newton Hamilton where it is almost completely exposed in large cuts on the Pennsylvania Railroad. Lithologically, this rock is very like the Marcellus, but its fauna contains fossils which set it off from the other black shale assemblages encountered in our Middle Devonian. Both the limy beds and the black shale carry Onondaga fossils with Middle Devonian affinities. Most of the black shale fossils are small mollusks, including coiled cephalopods. It is referred to as the Beaver Dam black shale from a brook at the type locality. (See Figure 35.)

Table XX, Composite Onondaga Section of Newton Hamilton.

	Feet
Marcellus black shale, exposed	39
Onondaga group	
Selinsgrove limestone	
g) Limestone, sandy, gray, brown-weathering, carries pyritiferous nodules. Well-rounded sand grains are present. Fossiliferous	4
f) Limestone, gray, massive, with impure black shale partings in midst. Conchoidal fracture	1-2
e) Shale, dominantly, black and fissile with large, calcareous concretions; beds merge into overlying limestone	19
d) Similar to (e) but fewer, more scattered concretions. No concretions from 40 feet below (e) to base of (d); thin sandstone partings in lower portion	78
This is the *Beaver Dam black shale;* its upper and lower limits are vaguely defined in (e) and (c) respectively.	
c) Similar to (d) but concretions again plentiful. They here appear sandy and show shale laminations on weathered surfaces. Unweathered concretions consist of dense, black limestone	22
d) Similar to (c); concretions are rare, but large, up to 5 feet, and some are septarian. Their abundance increases downward	67
a) Black shale and gray interbeds of platy limestone to 3-4 inches thick. The limestone dominates the lower 10 feet of this part of the section	17
DISCONFORMITY	
Oriskany sandstone, exposed	5

Onondaga correlations. The inter-relations of the members of the Onondaga group in Pennsylvania are shown in Figure 36. Though divided into four members, the formation shows a close unity throughout and is strictly related to the overlying Middle Devonian. Normally the Onondaga is succeeded through transitional beds by the Marcellus, but locally a disconformity may be recognized at this point. The base of the Marcellus, except in sections where that formation is incompletely present, as at the first Susquehanna gap at Rockville, is essentially synchronous through Pennsylvania. The Needmore shale and the Esopus shale are both in disconformable contact with the Oriskany. Except where local erosion may have been excessive, the top of the Oriskany appears to be assignable to the Ridgely sandstone. Thus are the limits of the Onondaga group drawn. Considering its several divisions, relations are transitional between the Needmore and the overlying Selinsgrove limestone throughout central Pennsylvania. A like relation obtains between the Esopus shale and the Buttermilk Falls limestone in eastern sections. The only exception is in the section at Palmerton. These four members carry about the same fauna, though its relative abundance varies. A comparison of their fossils is shown in Table XXII, page 156. Both limestones have a smaller fauna than the Needmore member, and the Esopus has the fewest fossils of all. The fossils have strong Hamilton affinities, and most of them recur in later beds. A few, notably *Anoplotheca acutiplicata*, are confined to the Onondaga in Pennsylvania. Several are common to the Oriskany and Onondaga, but of these, most are long-range species which transcend the limits of the Onondaga. The Lehigh River section suggests the correlation between the eastern and western Onondaga facies.

TABLE XXI

Central Pennsylvania	*Lehigh Valley*	*Monroe County*
Hamilton group	Hamilton group	Hamilton group
Transition (usually)	Transition	Transition
Onondaga group	Onondaga group	Onondaga group
Selinsgrove limestone	Buttermilk Falls limestone Selinsgrove limestone	Buttermilk Falls limestone
Transition	Transition	Transition
Needmore shale	Hazard paint ore Disconformity Esopus shale and sandstones, etc.	Esopus shale
Disconformity	Disconformity	Disconformity
Oriskany group	Oriskany group	Oriskany group

The cherty Buttermilk Falls and non-cherty Selinsgrove limestones seem to meet at the Lehigh. They are closely equivalent, a relationship further substantiated by their contacts elsewhere with the Marcellus, their faunal content and their passage into the subjacent members. Each shale makes up a definite unit in most sections, separable in turn by a disconformity from the still older Oriskany. Similarly, the Needmore and Esopus shales may be correlated. As just cited, both rest in disconformity upon the Oriskany and each grades up into one or the other equivalent limestones. Their respective faunas appear identical save for relative abundance.

The Hazard paint ore is correlated with the upper part of the Needmore member to the west and less surely with the upper Esopus to the east. This correlation is made because of its position in section and its intergradation with the underlying limestone. Its plentiful and varied fauna suggests more that of the Needmore shale than the other members, but this is based rather on quantitative, not qualitative data. Still, both the Needmore and paint ore are relatively rich in trilobites, organims not noticeably profuse in the other members. The local disconformity at the base of the paint ore may cut out much of the Esopus. The ore itself is thought to represent abnormal sedimentation following a brief interval of interrupted deposition. Its unusual fauna is certainly indicative of exceptional environmental conditions.

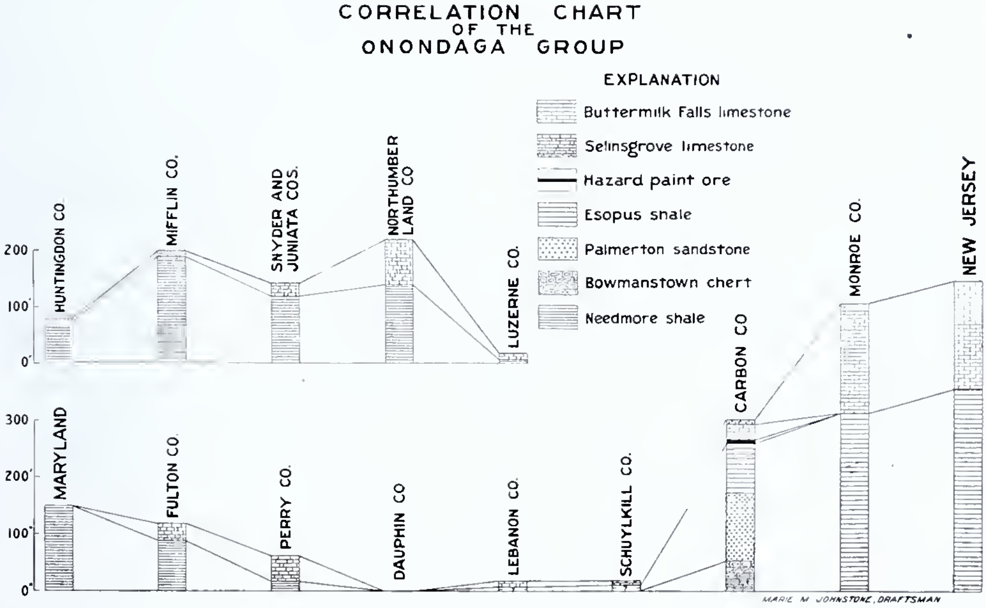


***Figure 36.* Correlation chart of Onondaga group in Pennsylvania.**

To the foregoing statements on inter-relations of the Onondaga members a summation of their faunas is added in Table XXII below. It is clear from the preponderance of evidence that the Onondaga cannot reasonably be sharply separated faunally from the younger Middle Devonian formations, but must, as premised, be treated as next of kin to the Marcellus and Hamilton. Lithologically there is a clear difference, despite a transitional contact. But, revising my recent practice of calling all three the "Hamilton group," I now simply apply Middle Devonian inclusively to the Onondaga, Marcellus, and Mahantango.

Table XXII, Onondaga Faunas

The following table of Onondaga fossils in Pennsylvania and adjacent regions is taken nearly verbatim from my previous account of the group and its organic contents, but the list for the paint ore has been completely revised in the light of thorough study of that faunule. The list of species from New Jersey does not include those of the Green Pond Mountain region.

FAUNA	Buttermilk Falls limestone	Selinsgrove limestone	Needmore shale	Beaver Run shale	Hazard paint ore	Esopus shale New Jersey	Onondaga	Maryland Onondaga
Sponge, undetermined		x						
Streptelasma sp.			x					
Zaphrentis simplex	x	x	x					
Z. prolifica		x	x					
Z. sp.	x	x	x				x	
Amplexus hamiltoniae			x					
Cystiphyllum sp.	x							
Cyathophyllum cf. *conatum*					x			
C. sp.	x							
Favosites limitaris					x			
F. sp.	x					x		
Ceratopora sp.			x					
Cladopora sp.	x							
Corals, undetermined	x	x	x					
Polygnathus sp.								x
Taonurus sp.		x				x		
"Crinoidea," columnals	x	x	x		x			
Cystodictya gilberti		x						
C. sp.					x			
Fenestella sp.	x	x			x		x	
Polypora cf. *distans*		x						
P. cf. *hexagonalis*		x						
P. sp.					x			
Conscinium cf. *striaturum*		x						
Bryozoa, undetermined			x		x			
Lingula ligea			?		x			
L. delia		?						
L. cf. *nuda*								x
L. sp.		x		x		x	x	
Orbiculoidea lodiensis var. *media*		x	x	x				x
O. sp.			x	x		x		
Craniella hamiltoniae								x
Pholidops cf. *areolata*			x					x
P. sp.					x			
Pholidostrophia pennsylvanica		?	x					x
Leptostrophia perplana	x	x	x		x		x	x

Table XXII, Onondaga Faunas—Continued

FAUNA	Buttermilk Falls limestone	Selinsgrove limestone	Needmore shale	Beaver Run shale	Hazard paint ore	Esopus shale	New Jersey Onondaga	Maryland Onondaga
L. sp.			x					
Stropheodonta demissa					x			
S. patersoni				x	x			
S. inequistriata		x	x		x			
S. concava					?			
Douvillina sp. nov.		x						
Leptaena rhomboidalis	x	x			x		x	
Leptaenisca australis			x					x
Schuchertella pandora			x		x		x	x
S. variabilis					x			x
S. cf. *perversa*		x	x					x
Chonetes mucronatus	x	x	x		x			x
C. hemisphericus		x						
C. buttsi		x	x	x				
C. setiger					x			
C. cf. *setiger*			x					
C. coronatus			x					
C. scitulus			x					
C. lepidus					x			
C. rugosus								x
C. sp. nov.				x				
C. sp.	x	x	x	x		x		
Eodevonaria arcuata			x		x	x	x	
Anoplea nucleata		x	x					x
Strophalosia truncata		x	x					x
Productella navicella		x						
P. sp.			x					
Dalmanella lenticularis			x		x			x
D. sp.			x					
Rhipidomella vanuxemi		x	x				x	x
R. leucosia								x
R. cyclas								x
Schizophoria striatula					x			
S. propinqua					x			
Amphigenia cf. *elongata*						x		
Camarotoechia sp.		x						
Centronella cf. *ovata*								x
Cranaena romingeri		x						
Liorhynchus cf. *multicosta*			x					
L. sp.			x					
Tropidoleptus sp.			x					
Atrypa reticularis	x	x	x		x		x	
A. spinosa	?							
Cyrtina hamiltonensis	x		x					
C. sp.			x					
"*Spirifer*" cf. *varicosus*		x					x	
"*S.*" *raricostus*			x					
"*S.*" *acuminatus*		x						

Table XXII, Onondaga Faunas—Continued

FAUNA	Buttermilk Falls limestone	Selinsgrove limestone	Needmore shale	Beaver Run shale	Hazard paint ore	Esopus shale	New Jersey Onondaga	Maryland Onondaga
"*S.*" *marcus*						X		
"*S.*" *duodenarius*						X		
"*S.*" *macrothyris* (?)					?			
"*S.*" *audaculus* (?)					?			
"*S.*" cf. *octocostatus*			X					
"*S.*" sp.		X				X		
Elytha fimbriata			X		X		X	X
Ambocoelia umbonata		X	X					X
A. nana			X					
A. sp.		X	X					
Nucleospira concinna			X					X
*Anoplotheca acutiplicata**	X	X	X	X	X	X	X	X
A. concava							X	
A. camilla		X		X				X
A. sp. nov.		X	X					
Martinia? sp.		X						
Vitulina pustulosa			?					
Pentagonia unisulcata	X	X						
Pentamerella arata					X			
Brachiopoda, undetermined		X	X			X		
Euthydesma sp.								X
Panenka alternata								X
P. cf. *dichotoma*								X
P. obsolescens								X
P. cf. *multiradiata*			X					X
P. sp.			X	X				X
Buchiola halli								X
Nucula corbuliformis			X					X
N. sp.			X					
Nuculites modulatus			X					X
N. triqueter				X				X
Palaeoneilo constricta			?					X
P. emarginata				?		X		
Liopteria sayi			X					
L. laevis								X
Conocardium sp.	X			X				
Actinopteria sp.		X						
Schizodus sp.		X						
Aviculopecten equilatera								X
Modiomorpha subalata								X
M. sp.			X					
Pelecypoda, undetermined				X				
Pleurotomaria lucina				X				
P. crassa		X						
P. sp.			X					

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* Some of the Esopus examples may be *Leptocoelia* and imply Oriskany derivation of at least one element of the fauna.

Table XXII, Onondaga Faunas—Continued

FAUNA	Buttermilk Falls limestone	Selinsgrove limestone	Needmore shale	Beaver Run shale	Hazard paint ore	Esopus shale	New Jersey Onondaga	Maryland Onondaga
Bellerophon leda		x						
B. cf. *pelops*			x					
B. sp.			x					
Buchanopsis lyra				x				
Nanticopsis sp.			x	x				x
Loxonema hamiltoniae								x
L. cf. *pexata*			x					
L. sp.			x				x	
Platyceras sp.	x		x	x			x	
Diaphorostoma lineatum					x			
Platystoma cf. *euamphaloides*								x
P. sp.		x		x				
Styliolina fissurella		x	x	x				x
S. sp.		x	x	x				
Tentaculites bellulus	x	?						
T. sp.			x					
Conularia undulata				x				?
C. sp.				x				
Enchostoma sp.								?
Coleolus curvatus			x					
C. tenuicinctus				x				
Hyolithus cf. *aclis*			x					
H. cf. *principalis*			x					
Orthoceras cf. *subulatum*			x					
O. sp.		x	x	x				
Bactrites aciculum		x	x	x				x
B. sp.				x				
Paradisceras discoideum								x
Agoniatites expansus								x
Gonitatites, undetermined		x	x	x		?		x
Cephalopoda, undetermined			x					
Proëtus sp.			x					
Acidaspis callicera			x					
Phacops cristata		x	x		x			x
P. cristata var. *pipa*		x	x		x		x	x
P. rana		x	x		x		x	
P. bufo	?							
P. sp.		x	x		x			
Greenops boothi, var. *calliteles*		x	x					
G. aspectans		x	?					
G. anchiops						x		
G. sp.		x	x					
Odontocephalus selenurus		x					x	
O. aegeria		x	x		x		x	
O. cristata			x					
O. sp.			x					

Table XXII, Onondaga Faunas—Continued

FAUNA	Buttermilk Falls limestone	Selinsgrove limestone	Needmore shale	Beaver Run shale	Hazard paint ore	Esopus shale	New Jersey Onondaga	Maryland Onondaga
Conolichas eriopis					x			
Cyphaspis cf. *stephanophora*								x
C. minuscula					x			
Phacthonides gemmaeus					x			
Trilobita, undetermined		x						
Lepterditia ? cf. *subrotunda*			x					x
Bollia ungula			x					x
Bollia? obesa			x					x
B. sp.			x	x	x			
Bythoeypris favulosa			x					
B. sp.			x					
Ulrichia eonradi			x					
U. sp.					x			
Octonaria stigmata			x					
Ostracoda, undetermined		x	x		x			
Phyllocarid, undetermined				x				
Pisces, undetermined				x				
Plantae, undetermined			x			x		

CHAPTER V.

MIDDLE DEVONIAN, Continued. ERIAN STAGE

Hamilton Group

The preceding chapter opens with a general discussion and history of the development of the concept of the Middle Devonian as applied in Pennsylvania. The balance of the chapter is dedicated to descriptions of the lower part of the Middle Devonian, the Onondaga group. It yet remains to comment upon the rest of the Middle Devonian, the Hamilton group, using the term in a circumscribed manner, as has been noted and will be defined again presently. So important is this portion of the Devonian that it has been segregated in a separate chapter.

Hamilton defined

In her admirable summary of New York geology, Dr. Goldring writes (104; pp. 386-7):

> The *Hamilton beds* were named originally from typical exposures at West Hamilton, Madison County (Vanuxem '40). These beds which are represented in the east by sands and arenaceous shales and in the west by black shales, calcareous shales and limestones, are on the whole richly fossiliferous. The Hamilton beds form a thick wedge of clastic materials which thin westward with numerous accompanying shifts or facies both in the character of the rock and the fauna. Hall and Vanuxem in their final reports included in this group the Skaneateles shale, Olive shale, Ludlowville shale, Encrinal limestone and the Moscow shale. Dana enlarged the term to include the Marcellus shale and the Tully limestone. Until recently, the term has been used to include everything between the Cardiff shales and the Tully limestone, that is, the Skaneateles, Ludlowville and Moscow formations. Very recent studies of the Hamilton beds have shown the necessity for some revisions, and for the details the student is referred to the paper embodying the results (Cooper '30). These studies have shown "that the black muds of the Marcellus, often affiliated with the Onondaga, thicken eastward and are gradually replaced by gray arenaceous shale. Concordantly, the Marcellus fauna grades eastward into one of Hamilton aspect. These phenomena have made it necessary to place the Marcellus formation in the Hamilton group, which, therefore, now consists in ascending order of the Marcellus, Skaneateles, Ludlowville and Moscow formations. The Skaneateles formation and several members in the higher formations show a similar westward shift of faunal facies from one of Hamilton aspect in the east to a modified Marcellus fauna in the west.

This description demonstrates that during nearly a century, the use of the term Hamilton has passed through many vicissitudes (cf. Cleland, 76). Some authors have argued for its restriction, others its expansion. Their disagreements are summarized by Cooper (78; p. 126):

> Dana (J. D., 63, p. 288) in his "Manual" had been using the name Hamilton in two different ways, one with a chronological sense, the Hamilton Period, and the other as a stratigraphic term, Hamilton group. These and

> other irregularities in geological nomenclature led Clarke and Schuchert (99i) to reorganize the stratigraphic nomenclature of the State, reviving many old names, among them the term, Erian, to serve in a chronological sense for the time included in the Marcellus and Hamilton.
>
> In a revision of the stratigraphy of the State, Clarke (03g, p. 22) felt a need for the subdivisional terms that had been long in disuse and, therefore, revived the names Skaneateles, Ludlowville, and Moscow as subdivisions of the Hamilton and the Marcellus was set out as a division correlative with the Hamilton. This grouping persisted until Schuchert (Pirsson, L. V., and Schuchert, C., A Textbook of Geology, Pt. II, p. 309, 1924) placed the Marcellus in his "Onondaga-Marcellus group" on the basis of the stratigraphic relationships of these groups described by Clarke (1901).
>
> The results of the present study emphasize the close faunal and stratigraphic relationships of the Marcellus with the Hamilton and show that the Marcellus is actually a facies of the Hamilton. Therefore, the Marcellus has been returned to its former position at the base of the Hamilton and is considered as a formation of the same value as the others of the Hamilton - - - -.

So much for the uses of Hamilton in the type New York region. How much and how well can these definitions apply to Pennsylvania? Can we use them, or must we set up our own nomenclature? The probability is that a compromise will best suit the situation, and such is proposed in the following discussion.

Rogers evidently had the more restricted use of Hamilton (that is, post-Marcellus but pre-Tully) in mind when he correlated the "Hamilton Group of New York" with his "CADENT SHALES" lying between recognized equivalents of the black "Genesee Slate" and "Marcellus Slate" (177). Such, too, was the use accepted by I. C. White of the Second Survey (228, 229, 230), but White was prone to employ the same name in more than one sense simultaneously. He used Hamilton, first for the lower part of Formation VIII as a sort of group term, and then as the middle of the same which he resolved into three parts:

c. Genesee shale
b. Hamilton sandy shales
a. Marcellus shales

Cleaves and I (257) used Cooper's definition of the Hamilton group in our work on the Middle Devonian in eastern Pennsylvania, to mean that it embraced the Moscow, Ludlowville, Skaneateles and Marcellus formations in descending order. This proved moderately satisfactory for that part of the State, but as studies were pushed westward, the New York sequence grew less useful. I still tried to continue this New York usage in central and southcentral Pennsylvania, but with modifications based upon lithology and faunal variations (242, 246). When studying my collections of Onondaga fossils and notes on that group, I became convinced of the close relationship between the Onondaga and the overlying Middle Devonian beds. I then suggested (251) that they be all bunched together as the Hamilton group, the term thus becoming synonymous with Middle Devonian. This suggestion was repeated shortly afterward in describing the correlations of the Middle Devonian among

New York, New Jersey, Pennsylvania and Maryland (254). However, even at that time, I remarked "I prefer to leave the question open until a general agreement may be reached between those interested in Middle Devonian terminology in the eastern United States." As no agreement has been reached since then, I feel at liberty to proceed with a modifying suggestion.

If Hamilton group and Middle Devonian are to be synonymous, one or the other term is superfluous. Obviously, Middle Devonian cannot as easily be eliminated under present usage. Therefore, Hamilton in this sense must be dropped. If it is to be retained at all, it must be redefined in a restricted, new, revised connotation. It is proposed, as stated in Chapter IV, again to use Hamilton as recommended by Cooper, that is, for beds included between the Onondaga below and Burket ("Genesee" of writers) or Tully, etc., above.

In Pennsylvania this makes the Hamilton a group term, for it includes units of formational rank. Theoretically, however, Hamilton may be as much a facies term as Marcellus or Catskill. In Pennsylvania this is a relatively small issue; for unlike New York, we have little or no direct concern with the assumption westward of a Marcellus black shale facies of the equivalent of what we are calling the Mahantango formation in central and eastern Pennsylvania. Our Middle Devonian before much of this alteration appears dives irrecoverably beneath the Allegheny Front. Conversely, we are only indirectly concerned with the change in "eastern" New York (Hudson Valley) and northcentral New Jersey where occurs the displacement of the Marcellus by a Mahantango facies fauna entombed in coarse clastics. There, the Hamilton group is merely the coarse, clastic facies of Middle Devonian marine sedimentation. Nevertheless, though we may speak of the Hamilton group, its facies significance must be constantly borne in mind.

The use of Hamilton group as distinct from the Onondaga group, therefore, accords with both ancient procedure and modern practice. It supplies a term of reference for the post-Onondaga Middle Devonian. Simply by saying Hamilton lithology, Hamilton facies, Hamilton fauna, the connotation may be taken to imply post-Onondaga conditions without having to add in explanation "*senso stricto*," use as of 1840, 1858, 1899," etc. Confusion is lessened, through simpler terminology. Therefore, Hamilton group will be hereinafter used for those Middle Devonian beds which separate the Onondaga from the basal Upper Devonian, be that Burket, Brallier, Tully or what not. Parenthetically, the Mahantango facies might, in Pennsylvania, be referred to faunally as the "*Spirifer*" *audaculus* beds. The included Marcellus formation, be it remembered, is a black shale facies of the Hamilton, as contrasted with the more arenaceous facies typified by the Mahantango.

Limits and Distribution

The upper limit of the Hamilton group in Pennsylvania has recently been elucidated (247). A brief paraphrase of my observations shows that between the Allegheny Front and the Delaware

Valley, the Middle-Upper Devonian contact is anything but monotonous. Nearly always the Hamilton group terminates in shale or sandy shale, usually carrying a Moscow fauna with a *Vitulina* zone at or near the top. In southcentral Pennsylvania the Moscow facies equivalent is probably absent. Resting in disconformity upon the topmost Hamilton, one may expect to encounter the Tully limestone, the Burket black shale, or Trimmers Rock sandstone. As will be shown in discussing the Portage group, this succession is explicable as transient marine stillstand succeeded by resumed westward offlap in early post-Hamilton time. The basal Trimmers Rock, where it rests upon the Hamilton in Monroe County, may be distinguished by an occurrence of *Hypothyridina*, but in Pike County there is no sure means known of separating the sandy, uppermost Hamilton, from the similarly arenaceous basal Portage which carries no Tully element nor black shale band. The inference is that there is here both lithic and biologic intergradation.

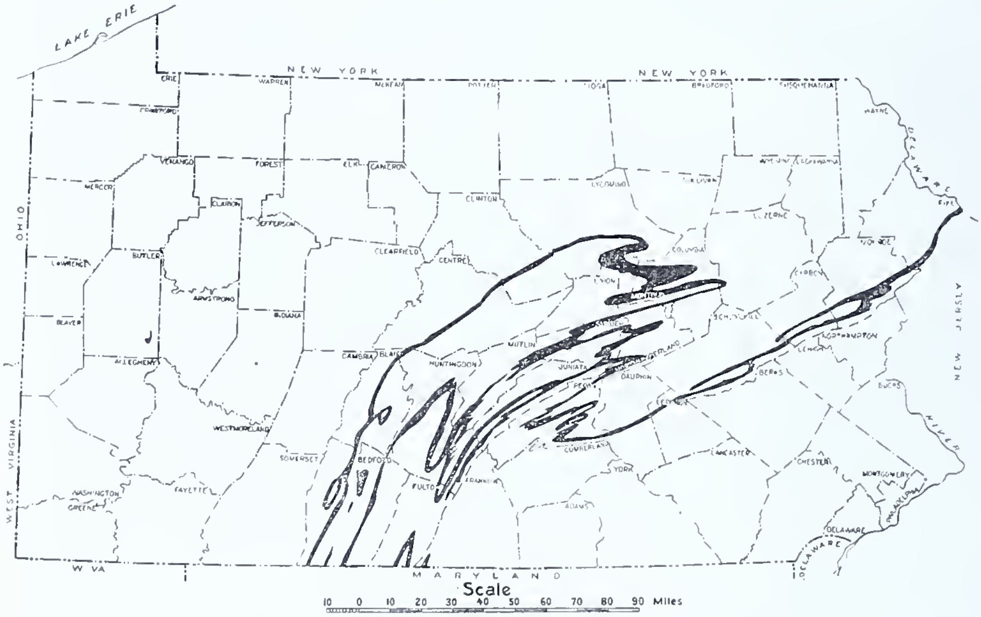
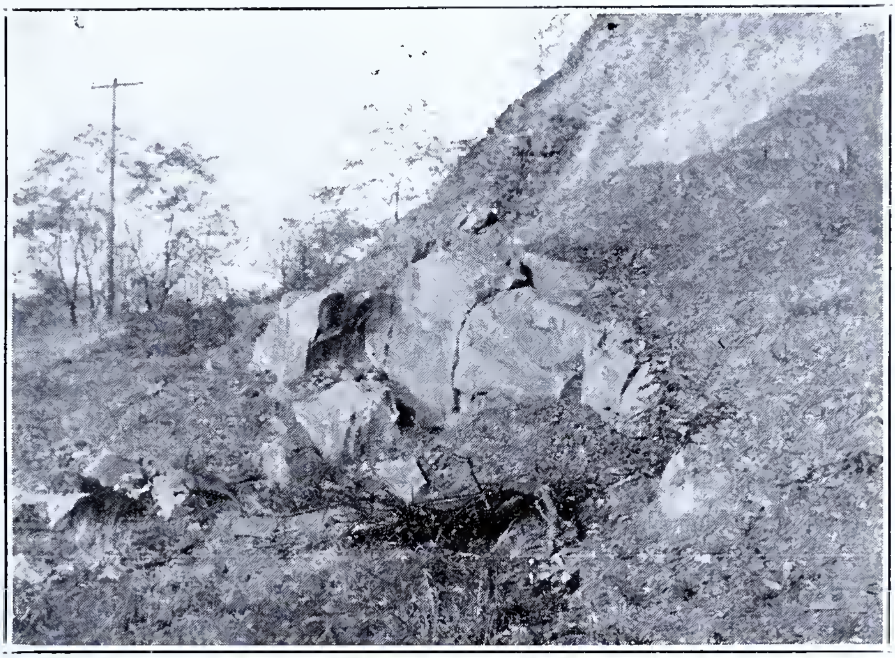


***Figure 37.* Sketch map showing distribution of Hamilton group in Pennsylvania.**

The lower limit of the Hamilton group can be sharply drawn only locally throughout our Middle Devonian terrane. True to its facies nature, the upper Hamilton or Mahantango is transitional with the Marcellus whose relations to the Onondaga I have described. The near faunal and lithologic relations of the Mahantango and Marcellus are criteria which require their close grouping together. Where the more abundant Skaneateles facies fauna appears instead of the usually meager Marcellus facies, I have drawn the line even before an appreciable lithologic change is apparent. From Perry County east to the Schuylkill, the hard Fort Hunter sandstone (cf. *Sequence c* Chapter IV) occurs near the base of the Skaneateles, but is not a particularly valuable key bed.



Photograph by Bradford Willard

Figure 38. **Fort Hunter sandstone at type locality, southernmost quarry at Rockville, Dauphin County.**

The wide distribution of the Hamilton in Pennsylvania is illustrated in the map, Figure 37. The Hamilton group enters Pennsylvania from the east of Matamoras, as a narrow band which underlies the north side of the Delaware Valley. This band continues west across central Pennsylvania to the Allegheny Front and south into Maryland, a distribution noted in Chapter IV.

Hamilton Divisions

In tracing the Hamilton across Pennsylvania from its entrance by way of the Delaware Valley at the east to its submergence at the Allegheny Front on the west or passage into Maryland along our southcentral border, it is evident that the group admits of analysis into several small units. Clear cut here, any of these may become obscure or totally unrecognizable yonder. The description of these subdivisions and their intercorrelations are topics of considerable importance. The correlation chart, Figure 40, shows graphically these subdivisions and their correlations across Pennsylvania.

The Hamilton sequence in New York has been cited; in eastern Pennsylvania the succession is analogous. The character changes steadily southwestward; and, at the Mason-Dixon line, little remains directly correlatable with the Hamilton of New York. There is only a general similarity. As the resemblance fades, certain lithologic anomalies obscure the more distinct eastern divisions. At the same time, units not known in the east develop. The sequence in eastern

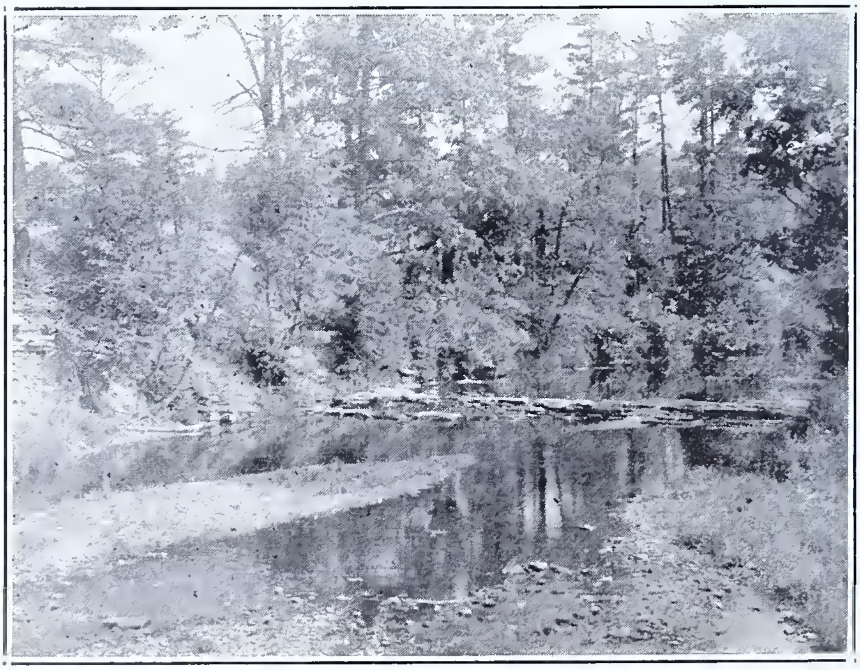
Pennsylvania as typified in Monroe, Carbon and even as far west as Schuylkill County, is:

HAMILTON GROUP

- Mahantango formation
  - Moscow facies. *Vitulina-"Spirifer" tullius* zone common at or near top.
  - Ludlowville facies. Storm-roller zone in lower part. Centerfield coral zone at or near base.
  - Skaneateles facies. Berwyn and Delphi equivalents probably present in east. Fort Hunter sandstone near base, locally.
- Marcellus formation

THE MARCELLUS FORMATION

In the discussion of the Onondaga group, I described its relations to the next higher division of the Middle Devonian, the Hamilton group. The fact has been stressed that these two groups, the Onondaga and Hamilton, are faunally nearly related and that, save in the restricted region of the middle Susquehanna Valley and along the lower Juniata, the two mutually intergrade without sign or hint of disconformity. Yet this contact separates two unlike phases of Devonian sedimentation in Pennsylvania, rivaled in contrast only by the dissimilarity between the Helderberg and Oriskany groups. The Onondaga is dominated by calcareous rocks. Even where true limestone is lacking, the shales which supplant it are limy. The Marcellus



Photograph by Bradford Willard

Figure 39. **Local limestone lens in Mahantango shales, Raystown Branch, Juniata River, near Manns Choice, Bedford County.**

and succeeding beds of the Hamilton are non-calcareous, clastic deposits. Yet, the black shale, with its pelagic fauna and interbedded limestones, locally developed in the Onondaga, is a true foreshadowing of coming Marcellus conditions. Nevertheless, despite the close Onondaga-Marcellus affinities and the suggestion of the beginning of Marcellus environment in local developments of the Onondaga the physical change on the whole is pronounced. Calcareous deposition failed to return during Middle Devonian time. True, there are a few thin limestone bands in restricted areas in the Marcellus, and "limestones," most of them coquinites, are known in still higher beds, but they are naught compared in either extent or thickness to the rest of the strata. Even the Centerfield coral zone of the basal Ludlowville is nowhere a true limestone. Rather it is finely arenaceous mud, full of calcareous, organic remains. This important sedimentary difference at the end of Onondagan time marks the beginning of the gradual marine recession and concomitant filling of the Appalachian geosyncline. Momentarily interrupted at the opening of late Devonian time, that is, in the early Portage, when the Tully limestone and its black shale complementary correlate, the Burket, spread eastward, sedimentation presently resumed its steady march, to culminate in the continental Catskill facies. These non-marine beds had their inception eastward in rather early Middle Devonian time, and their progressive off-lap westward was all but uninterrputed to the dawn of the Mississippian period. How well all this was told by Lesley in his Second Survey summary (137; pp. 1194-5):

> We enter now [Marcellus] upon an age or series of ages of mud and sand, leaving the limestone world beneath our feet. The sea deepens to receive the black deposits of the *Marcellus*, and then the *Hamilton* sand; then again the soft black mud of the *Genesee;* and again the fine sand of the Portage; then the vast inpour of mingled mud and sand of the Chemung; and finally an interminable series of gray and red sands, muds and occasionally gravel, the *Catskill* formation, which finishes the *Devonian system*, and prepares an oceanic bottom for the *Carboniferous system.* Ten thousand feet of these Devonian sediments remain in the deeper folds of middle Pennsylvania, and their upturned edges may be studied along innumerable zigzag outcrops.

The type locality for the Marcellus in New York State lies in a region classic in Devonian lore. Recent studies of Cooper have revised our knowledge of the New York Marcellus, its several divisions, stratigraphic character, and the history of the term (78; pp. 129-130):

> To the west of Flint Creek the entire Marcellus formation consists of a relatively thin layer of black shale, not divisible into units, but in the central and eastern parts of the state it becomes much thicker and is clearly divisible into a number of well defined members. In a like manner the Marcellus is marked by a decided change in facies when followed from west to east. In the western part of the State the "Marcellus or Leiorhynchus fauna" is dominant but in the passage eastward it is replaced by the Hamilton fauna, except in the lowest part of the formation.
>
> The Marcellus has undergone considerable revision since the name was proposed first by Hall (39, p. 295). The term was first used to include the shale at Marcellus between the top of the Onondaga limestone and the horizon marking the first appearance of a true Hamilton fauna. A thin band of limestone (subsequently termed the Stafford limestone)

occurred in the midst of Hall's Marcellus and was used as a plane of reference in discussions of these rocks. In 1840 Vanuxem (40, p. 379) described a lower, black, fissile shale and an upper blue-black or dark gray shale, the former being the lower Marcellus, and the latter the upper Marcellus. In 1904 Clarke and Luther (04b, pp. 14-17) subdivided the Marcellus into the Marcellus and the Cardiff in a region east of the eastern limit of the typical Stafford limestone. But they fell into confusion because farther west the shale below the Stafford is jet-black and the shale above the Stafford is lithologically like the Cardiff. They, therefore, defined the Cardiff as lying above the Stafford when actually it lies in the Marcellus and is overlain by the Mottville, which is the eastern equivalent of the Stafford, as clearly defined by Smith (B., 16). Since the Stafford is actually the equivalent of the basal bed of the Skaneateles, it is necessary to exclude this member from the Marcellus.

In Pennsylvania the occurrence of the Marcellus black shale was recognized by Rogers, who, in 1858 (177), designated it as the lowest of the three members of his Cadent Series, the "CADENT LOWER BLACK SLATE (*Marcellus Slate of New York*)." The Second Survey except for confusing the Marcellus with the "Genesee" in and near Bald Eagle Valley, did a good piece of work on this shale. Because it is the most widespread unit and yet the most constant in lithology among all the Devonian formations, perhaps of all Paleozoic formations in the State, its obviously distinctive features could hardly escape even the least observant of Lesley's band. They recorded its position, thickness and distribution generally with highly commendable accuracy. Lesley's final summary (137) of the formation is admirable, and it might well be quoted entire and applied almost unmodified today. He distinguished certain divisions of the Marcellus in eastern Pennsylvania, separable chiefly upon their color, black in the upper and lower, and gray in the median portions. My observations show that the upper and lower black parts are geographically restricted and hardly valid subdivisions. Rather, the whole is more nearly in agreement with Lesley's characterization of the middle part. While it must not be inferred that black shale is absent from our eastern Marcellus, this facies becomes prominent only to the west, but the Second Survey's characterization, "gray, slaty sandstone," is the predominating eastern lithic type.

Parenthetically, it is interesting to observe that, even at the close of the nineteenth century, Lesley found it imperative constantly to caution against the misconception that black shale meant coal. His somewhat detailed mention of the Marcellus iron ores seems misplaced emphasis today, when our Devonian ores, of no present commercial value, are ignored by the economic geologist. Yet the day may come when these lean, little beds shall again be worked to supply an iron-poor civilization.

Distribution. Though not commonly a thick formation, the Marcellus has, as just remarked, probably the most uninterrupted distribution of any of our Devonian sediments. Entering the State from New York at Matamoras on the Delaware, it underlies the low ground bordering the river, its top occasionally showing in the base of the bluffs which rise to the northwest. Westward, to the Susquehanna Valley, the formation follows a nearly straight line, broken

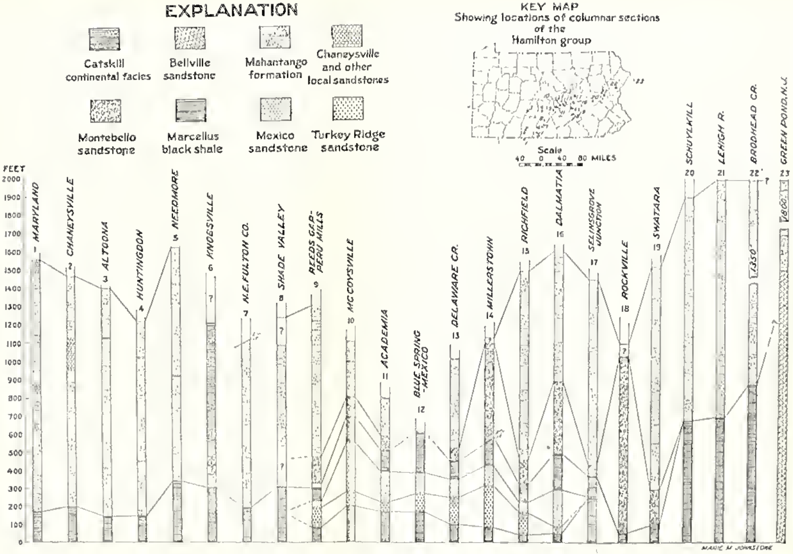


Figure 10. Correlation chart of Hamilton group in Pennsylvania.

only by minor divergences. In the Susquehanna and Juniata valleys, the Marcellus outcrop weaves back and forth, skirting the bases of the small ridges of Montebello sandstone. It disappears westward beneath the Allegheny Front to reappear no more in Pennsylvania. Southward, it passes from the State as several narrow bands of outcrop in Franklin, Fulton and Bedford counties.

Thickness. Save in our eastern sections or in the exceptionally arenaceous facies of the formation in the middle Susquehanna-Juniata valleys region, the Marcellus has no great thickness. The variations are given in Figure 40, showing Hamilton correlations. A maximum of 880 feet is recorded in Monroe County whence it drops to 675 feet on the Schuylkill and thence thins rapidly (perchance partly due to faulting) to only 90 (?) feet on the Swatara and but 50 odd at the gap of the Susquehanna in southeastern Perry County. A rise to about 75 feet is noted in Perry County. Thence northward, an influx of sandstone members again raises the Marcellus thickness in Juniata County to nearly 700 feet. It falls off again suddenly to the north and west as these sandstones drop out, so that along the Allegheny Front, between 150 and 200 feet would appear a fair estimate of its thickness. It should be noted that Stevenson (198; p. 82) gave a thickness of 794 feet in Bedford and Fulton counties, but he included lithologically similar beds now grouped because of faunal evidence in the overlying Mahantango formation.

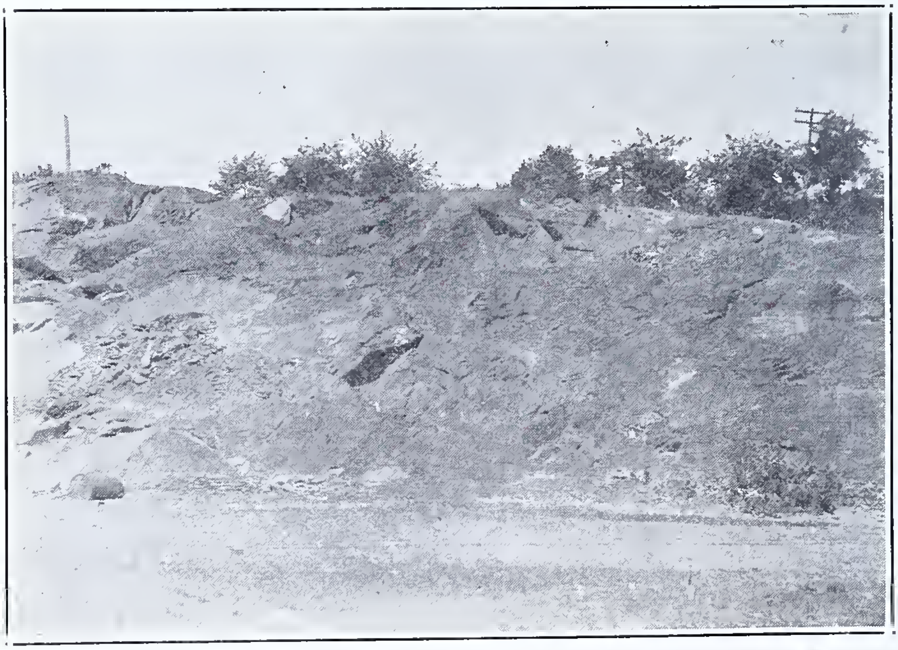
Character and correlation. Despite its rather uniform character, the lithology of the Marcellus formation in Pennsylvania does perceptibly vary over wide areas. The several phases are not particularly striking save in two instances. Nevertheless, some are sufficiently pronounced to serve in a limited way toward differentiation. The New York Marcellus is considerably subdivided; portions of the formation in Pennsylvania have lithologies corresponding to three of the New York members, recently described by Cooper (78; pp. 131-133):

> *Chittenango member.* This name is applied to the jet-black, fissile shale above the Cherry Valley limestone from eastern New York nearly to Cayuga Lake. The rock readily crumbles to paper-thin flakes so that some outcrops appear as a pile of thin chips. Huge septaria and smaller calcareous concretions are abundant. The shale is non-calcareous and nearly barren of fossils. It is separately designated because of these last two characteristics and because it represents only a part of the time interval of the Oatka Creek shale of western New York.
>
> *Union Springs member.* This new name is applied to the thin alternating beds of black limestone and sooty shale between the top of the Onondaga limestone and the Cherry Valley limestone. The type section is in the upper part of Wood's Quarry, 1 mile south of Union Springs (Cleland. 03a, pl. 4), Cayuga Lake, where the relation of this member to the Cherry Valley may be studied. East of the type section it increases in thickness, and the relative amount of shale to limestone also increases. At the type section the member is 17 feet; at Marcellus it is 13 feet, and at Oneida Creek above Stockbridge Falls it is 25 feet thick. Traced westward the relative proportion of limestone to shale increases and the member thins noticeably, being only 9 feet thick on Flint Creek a short distance above Phelps. West of Phelps this member is not known.

> *Cardiff shale.* In their report on the Canandaigua-Naples quadrangles, Clarke and Luther (04b, p. 16) named the grey upper Marcellus, the Cardiff shale. Their type section, near the settlement of Cardiff in the Onondaga Valley, extends upward from the black Chittenango shale to the fossiliferous Mottville member of the Skaneateles. Clarke and Luther erroneously supposed this dark grey shale to be identical with a similar shale that lies above the Stafford limestone in western New York, and so defined the Cardiff as being above the Stafford. But since the Mottville has been traced to Cayuga Lake, where it directly overlies the Oatka Creek shale, it is evident that the Cardiff has disappeared, probably by a westward gradation into black shale........... The Oatka Creek shale is thus probably the depositional equivalent of the Cardiff and the Chittenango.

It should be observed that the New York Marcellus contains besides these units, the Oatka Creek shale, Cherry Valley member (a limestone), Bridgewater member, Solsville member and Pecksport member, none of which has been distinguished in Pennsylvania. The few limestone bands or lenses in our more western Marcellus exposures lack the large ammonoids so characteristic of the Cherry Valley member. The inadvisability of the use of the name "Cardiff" has been commented upon in the footnote of *Sequence d,* page 139. The name is not adopted here.

Where the Marcellus is first seen in eastern Pennsylvania, in the Delaware Valley and in the neighborhood of the Stroudsburgs, Monroe County, it is a rather dark to medium gray or almost black shale, usually finely arenaceous. The lithology is closely allied to that assigned the "Cardiff" in New York State; but, since the precise correlation cannot be established and there is doubt as to the validity



Photograph by Bradford Willard

***Figure 41.* Quarry in Brodhead (Marcellus) shale, north edge of Stroudsburg, Monroe County. Bedding nearly flat; note joints and cleavage**

of the term "Cardiff," the name *Brodhead member* is here introduced, for this finely arenaceous phase of the Marcellus. It is derived from its exceptionally good development in the valley of Brodhead Creek, Monroe County. In a stone quarry in the northern edge of Stroudsburg, typical Brodhead shale is uncovered for 20 to 30 feet and is highly fossiliferous. This zone is estimated to be some 130 feet above the top of the Onondaga. The faunule includes the following (233 *et seq.*):

Bryozoa, indet.
Lingula cf. *delia* Hall
L. ligea Hall
Orbiculoidea sp.
Craniella cf. *hamiltoniae* Hall
Craniella?
Chonetes mucronatus Hall
C. scitulus Hall
C. setiger (Hall)
Strophalosia truncata (Hall)
Camarotoechia prolifica Hall
Liorhynchus limitare (Vanuxem)
L. laura (Billings)
L. laura (?) (Billings)
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (?) (Conrad)
Ambocoelia umbonata (Conrad)
A. nana Grabau
Brachiopod, indet.
Panenka costata Hall
Nuculites triqueter Conrad
Liopteria laevis Hall
Lunulicardium curtum Hall
Actinopteria muricata Hall
Nyassa subalata Hall
Aviculopecten invalidus Hall
A. scabridus Hall
Allocardium alternatum (?) Hall
Modiomorpha alta (Conrad)
Styliolina fissurella (Hall)
Nephritoceras bucinnum (Hall)
Bactrites cf. *clavus* Hall
Homalonotus dekayi (Green)
Phyllocarida, indet.
Onychodus sigmoides (?) Newberry
Plantae, indet.

A closely similar though less diversified faunule was collected about 200 feet higher in the formation in exposures along the east side of State Highway 90 north of Stroudsburg. These faunules in their specific variety and abundance of individuals are unique for eastern and central Pennsylvania. Throughout most of those districts the Marcellus population consists of stray examples of *Liorhynchus "limitare"* and *Styliolina fissurella* to the near exclusion of all other organisms. A few exceptions to this statement are recognized in scattered localities, and these faunules will be listed subsequently.

In the region of Stroudsburg the basal Marcellus passes down into the shaly top or transitional beds of the Onondaga limestone (Buttermilk Falls formation). The top of the Marcellus cannot be separated from the basal Mahantango formation by any more definite criterion than the appearance of the first Skaneateles faunule. The lithology changes very gradually. Continuing westward, Marcellus exposures are fairly common, but rarely satisfactory.

The Marcellus of the Lehigh Valley near Bowmanstown and Lehighton is poorly exposed. The section is complicated by folding and faulting, and usually only the higher part of the formation shows. The beds are dark, fissile, arenaceous shale correlated with the Brodhead member in Monroe County. From the Lehigh, the Marcellus formation may be traced westward. Two miles west-southwest of Summit in southern Schuylkill County, the lower Marcellus beds are well exposed. Dark, finely laminated shale with a gray-brown streak carries a few styliolinas. The lithology is more of the Chittenango than Brodhead type and is correlated questionably with the Shamokin member, or lower Marcellus black shale of central Pennsylvania, to be described subsequently. The higher beds, still somewhat resembling the Brodhead type, are seen in the Pennsylvania Railroad cuts southeast of Schuylkill Haven. They carry a few fossils suggesting transition into the Skaneateles formation:

Lingula sp.
Orbiculoidea minuta Hall
Craniella cf. hamiltoniae Hall
Inarticulate brachiopod, undet.
Camarotoechia dotis Hall
Liorhynchus limitare (Vanuxem)
Actinopteria cf. *subdecussata* Hall
A. muricata Hall
Leptodesma cf. *rogersi* Hall
Modiomorpha alta (Conrad)
Styliolina fissurella (Hall)
Phyllocarid, indet.

The next notable outcrop of the Marcellus is on the east side of Swatara Creek below Suedberg, where the formation has an estimated thickness of 90 feet. The dark, slightly arenaceous shale carries 3 or 4 feet of black, argillaceous limestone at the base next to the Onondaga (Selinsgrove) limestone. The lithology of the noncalcareous beds suggests the Brodhead member more than did the exposure at Summit, but the correlation is uncertain; and the argillaceous limestone at the base may correlate with the Union Springs member of New York. The exposure at best is poor, but a comparatively large faunule of Onondaga aspect was collected:

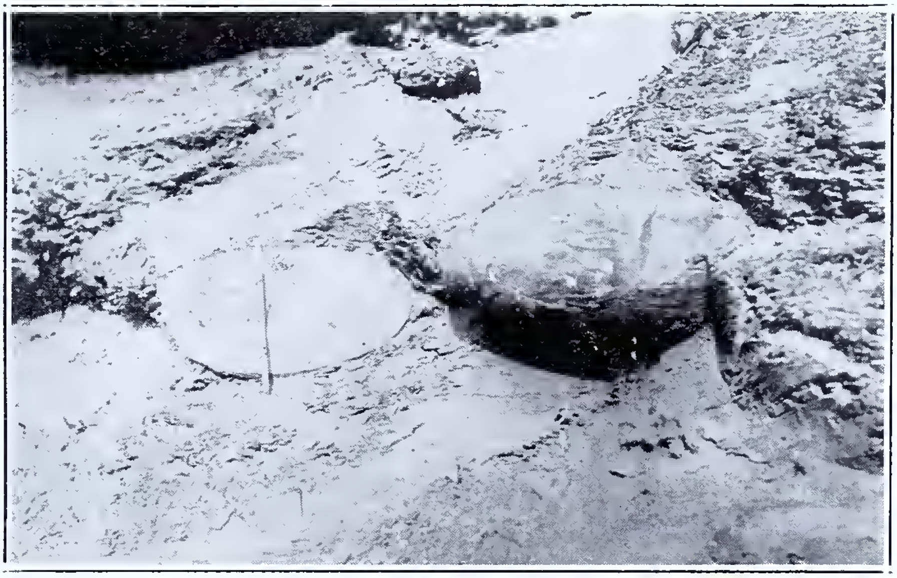
Bryozoa, indet.
Lingulella sp.
Leptostrophia perplana (Conrad)
Stropheodonta demissa (Conrad)
Leptaena rhomboidalis (Wilckens)
Chonetes coronatus (Conrad)
C. scitulus Hall
C. cf. *setiger* (Hall)
C. cf. *lepidus* Hall
C. vicinus (Castelnau)
Rhipidomella vanuxemi Hall
Liohynchus limitare (Vanuxem)
Actinopteria cf. *doris* Hall
Pelecypod, indet.
Styliolina fissurella (Hall)
Ostracod, undet.

Approaching the Susquehanna Valley, the Marcellus continues to thin to between 50 and 100 feet. In the southernmost of the Rockville quarries and across the river in an abandoned quarry south of Marysville (opposite the west end of the Pennsylvania Railroad bridge) the formation is not over 50 feet thick. This decrease is due to faulting, lack of deposition, or both. As the Marcellus passes up into the shaly base of the Montebello or Skaneateles, *Taonurus* may abound, but otherwise these shales are barren. Their stratigraphic position demands correlation with the upper black shale of the Marcellus, the Mahanoy member, of central Pennsylvania north of this area. The Marcellus is rather thin in Perry County, and is always black, fissile shale with or without iron ore at the base. This shale is also correlated with the Mahanoy member. It is in disconforamble contact with the limestone at the top of the Onondaga (Selinsgrove member) from which it is often separated by a very thin basal sandstone. (Figures 32 and 33.) The shale grades up into the base of the Montebello sandstone which may itself be shaly as at Rockville.

Northward along the Susquehanna or Juniata valleys from northern Perry into Juniata, Snyder and Northumberland counties, a remarkable change takes place in the lithology of the Marcellus. Instead of the characteristic dark gray or black, fissile to finely arenaceous shale, an abundance of sandstone, some of it rather coarse, makes its appearance. Because of this, the formation may be analyzed into four members:

Marcellus formation
  Mahanoy black shale
  Mexico sandstone
  Turkey Ridge sandstone
  Shamokin black shale

The highest and lowest, the Mahanoy and Shamokin members, are black, fissile shales of orthodox Marcellus appearance. Their maxima are 200 and 250 feet respectively. The former was named for Mahanoy Township, southwestern Northumberland County; the latter from Shamokin Creek in the western part of the same county. Usually, the two are indistinguishable lithologically and may be differentiated only when the intervening sandy members are recognized. Fossils are very scarce in the Shamokin and practically unknown in the Mahanoy. A magnificent section of these shale beds is exposed along the highway parallel to the railroad between Sunbury and Selinsgrove Junction. Here the black shales carry a few thin sandstones in the midst which may be attenuated remnants of the intervening arenaceous members to the southwest. In the lower part are many 2 to 3-foot ellipsoidal concretions. Locally these shales carry a little lime. The Shamokin member at Blue Spring near Mexico in Juniata County is bisected by a two-foot, dark coquinite composed chiefly of *Ambocoelia* shells. At Selinsgrove Junction during highway construction, I observed in the basal beds of the Marcellus, a sooty, fossiliferous bed suggesting strongly the Union Springs member of New York and rather similar basal strata at Swatara Gap *(q. v.)*. As stated, the Mahanoy is practically barren, but the Shamokin member



Photograph by Bradford Willard

Figure 42. **Concretions in the Marcellus black shale south of Sunbury, Northumberland County. The rule is one foot long.**

has yielded *Liorhynchus limitare, Styliolina fissurella* and a few other small forms. Most of these were found in the section below Sunbury. The two other members of the Marcellus in central Pennsylvania I described originally as follows (242; pp. 203-4):

> The Mexico sandstone member takes its name from the village of Mexico, in central Juniata County. It is exposed in a hill east of the town, and again in the Blue Spring section, southwest of Mexico, but attains a 275-foot maximum in the McCoysville section, whence it thins rapidly to nothing in western Juniata County. Eastward, it remains close to 100 feet thick, through the Dalmatia section, after which it almost immediately disappears. Northward, it dies out well within Juniata and Snyder counties. It is a fine sandstone, light gray to whitish, platy, and easily recognized by the fact that the bedding surfaces weather brown. It separates the Mahanoy and the Turkey Ridge members. Usually barren, an occasional Marcellus fossil has been found in this member.
>
> The Turkey Ridge sandstone takes its name from Turkey Ridge, which separates eastern Juniata and Perry counties. It is best seen in the Delaware Creek section, and is well exposed in several sections west thereof. Its maximum thickness, slightly over 200 feet, is in the Juniata Valley, whence it thins gradually to the east and to the west, having nearly identical areal distribution with the Mexico sandstone. No fossils have been discovered in this member. It is a flaggy to massive, comparatively coarse, hard, olive-gray sandstone and is often so strikingly similar in appearance to the Oriskany (Ridgely sandstone member) of the region as to be all but indistinguishable save on paleontologic data.

The following is a complete list of all Marcellus fossils so far discovered in the four members in central Pennsylvania:

Crinoidea, columnals
Lingulella sp.
Lingula ligea Hall
Orbiculoidea lodiensis var. *media* Hall
Chonetes scitulus Hall
Strophalosia truncata (Hall)
Liorhynchus limitare (Vanuxem)
Ambocoelia sp.
Buchiola sp. nov.
Liopteria laevis Hall
Modiomorpha cf. *alta* Hall
M. mytiloides (Conrad)
Styliolina fissurella (Hall)
Tentaculites bellulus Hall
Orthoceras subulatum Hall
Orthoceras?
Bactrites sp.
Goniatite, indet.
Phacops rana (Green)
Plantae, wood fragments, and others.

The origin of the sandy members of the Marcellus deserves special consideration. However, because the more prominent, younger Montebello sandstone occupies the same region, a description of the three with a discussion of their origin will be presented with the characterization of the similar but younger Montebello sandstone.

Along the Allegheny Front, the Marcellus is exposed in many places and is black, fissle shale like the Mahanoy and Shamokin members in central Pennsylvania. Probably it represents a coalescence of the two, with the Mexico and Turkey Ridge sandstones gone. Here, as in the east, the Marcellus interfingers with the Onondaga. No longer disconformable as in central Pennsylvania, the transition is reminiscent of our more easterly sections. Where, in central Pennsylvania, the Montebello sandstone may closely delimit the top of the Marcellus in many sections, along the Allegheny Front the first Mahantango faunule marks the base of the Mahantango formation. Of our most western or northwestern Marcellus, I have written (246; pp. 1282-3):

The Marcellus formation in Bedford County usually contains an abundance of the small pteropod *Styliolina fissurella* (Hall) and few, if any, other fossils. No faunal lists, therefore, have been presented............. on Canoe Creek [Blair County] the lower portion of the Mahantango formation is exposed as sandy, sparingly fossiliferous strata, which interfingers with the Marcellus below and may represent the Gander Run. This Marcellus is interesting, for in its midst there are thin limestones or beds of calcareous nodules which are the southernmost known example of a distinctive feature of this formation common in the northern sections. They are diagnostic and distinguish the Marcellus from the later Burket and Harrell ("Genesee") dark shales of the Portage, which along the Allegheny Front, are not known to include such beds. The Marcellus fauna on Canoe Creek..........shows a marked increase in number of species over Bedford County.

Bryozoan, undescribed
Strophalosia truncata (Hall)
Liorhynchus limitare (Vanuxem)
Ambocoelia umbonata (Conrad)
Leptodesma rogersi Hall
Styliolina fissurella (Hall)

No complete section of the Marcellus was found in Huntingdon County. At Entriken its top passes upward into dark, lower Mahantango sandstone and sandy shales. Thin limestone interbeds show along United States Highway 22, beside the State Reformatory west of Huntingdon. At the west side of Juniata College campus, Huntingdon, the black, fissile shale carries limestone concretions. Comparative lists of limestone and shale fossils at this place are given..............:

Limestone faunule:

Zaphrentis simplex Hall
Ceratopora intermedia (Nicholson)
Crinoidea, columnals
Orbiculoidea sp.
Ambocoelia umbonata (Conrad)
Styliolina fissurella (Hall)

Shale faunule:

Strophalosia truncata (Hall)
Productella spinulicosta Hall
Liorhynchus limitare (Vanuxem)
Ambocoelia umbonata (Conrad)
Pelecypoda, indet.
Styliolina fissurella (Hall)

....

In Mifflin County most of the Hamilton group has been eroded. At Newton Hamilton the lower beds have been preserved, but exposures are few and poor. Only the Marcellus surely was identified. It is, like that of Bedford County, black fissile shale without limestones and commonly carrying only *Styliolina fissurella* (Hall). ....Lower Mahantango fossils, or even outcrops of the formation, are particularly scarce in Lycoming County, but several Marcellus exposures have been discovered. Southeast of Jersey Shore, near River Mill School, is an exposure of characteristic black shale with limestone concretions. A diagnostic faunule was collected which is of exceptional specific richness for the Marcellus.

Crinoidea, columnals
Lingula sp.
Orbiculoidea lodiensis var. *media* (Hall)
Schuchertella variabilis Prosser
Chonetes vicinus (Castelnau)
C. sp
Strophalosia truncata (Hall)
Liorhynchus limitare (Vanuxem)
Ambocoelia umbonata (Conrad)
Buchiola sp. nov.
B. sp.
Palaeoneilo plana Hall?
Lunulicardium sp?
Pelecypoda, indet.
Styliolina fissurella (Hall)
Coleolus tenuicinctus Hall
Orthoceras sp.
Bactrites aciculum (Hall)
Agoniatites expansus (Vanuxem)
Goniatite, undet

As noted before, it is important in this region not to confuse the black Onondaga shale with the Marcellus. The abundantly fossiliferous character of the former is at once a distinctive feature not to be mistaken.

The Marcellus in Pennsylvania may be said to consist of several essentially synchronous facies whose relatively meager faunas are quite similar to one another. Disregarding the heavy sandstones, the Mexico and Turkey Ridge members, they being exceptional and confined to a comparatively small area, the Marcellus in the east is dominated by a finely arenaceous facies, the Brodhead member, which may be quite fossiliferous; in central Pennsylvania, the rock becomes nearly barren, fissle, black shale resembling the Chittenango of New York and carrying perhaps a suggestion of the Union Springs member of that State at the base; and along the Allegheny Front this black shale facies persists, but is clearly growing limy westward or northwestward. With increase in calcium-carbonate content, fossils become more diverse and profuse. In our Marcellus formation is the essence of a marine lateral sedimentary sequence. Off-shore, in relatively quiet water conditions, if not actual stillstand, accumulated the fine, black muds, and calcareous oozes. Farther shoreward come fine sands. We shall see later that, in northcentral New Jersey, the Marcellus changes to thick, coarse sandstone with a Mahantango facies fauna.

MAHANTANGO FORMATION

In our early work, Cleaves and I supposed the correlates of the New York formations of the upper part of the Hamilton group could be distinguished, particularly in eastern Pennsylvania (257). Additional studies have lead me to discount our first views to a certain degree. No doubt the three formations, Moscow, Ludlowville and Skaneateles, are more or less clearly discernable both lithologically and faunally, particularly faunally. However, it seems safer and wiser to extend the use of Mahantango formation for the post-Marcellus portion of the Hamilton group geographically eastward and refer to the probable correlates of these New York units as facies developed within the Mahantango itself. The general character of the Mahantango formation was discussed in Chapter IV. Its details must now be explained.

The *Moscow facies* in Monroe County occupies about 250 feet of fine-grained, dark-gray, platy sandstone and dark, argillaceous, sandy shale at the top of the Mahantango formation. Small concretions occur sparingly. On Brodhead Creek it carries the following fossils:

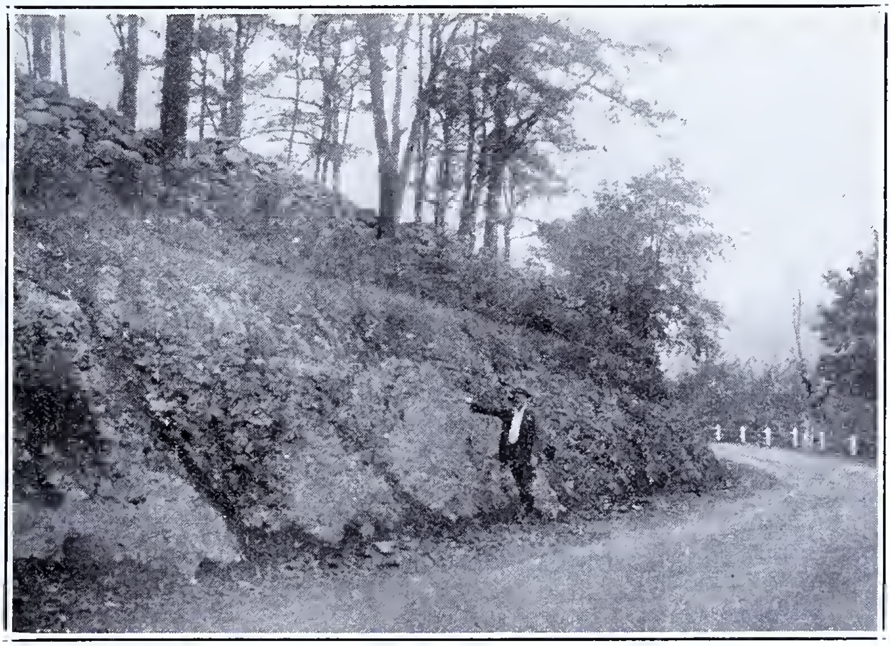
Crinoidea, columnals
Atrypa reticularis (Linnaeus)
"*Spirifer*" *granulosus* (Conrad)
"*S.*" *mucronatus* (Conrad)
"*S.*" *angustus* Hall
Grammysia arcuata (Conrad)
Cephalopod, indet.
Phacops cf. *rana* (Green)
Greenops boothi (Green)

This faunule, though just below the *Hypothyridina* beds (*Laurens*) of the basal Portage, lacks *Vitulina pustulosa* and *"Spirifer" tullius*, fossils which appear to be very rare or absent in the extreme east.* However, the highest Mahantango on the Lehigh yielded:

Chonetes scitulus Hall
C. cf. *vicinus* (Castelnau)
"Spirifer" mucronatus (Conrad)
"*S*" cf. *granulosus* (Conrad)
"*S.*" *tullius* Hall
Ambocoelia praeumbona Hall
Vitulina pustulosa Hall
Nuculites triqueter Conrad
Actinopteria decussata Hall
Pleurotomaria sp.

In Schuylkill County along the Reading Railroad north of Auburn the upper Moscow beds produced a more abundant fauna:

Favosites?
Crinoidea, columnals
Chonetes scitulus (Hall)
C. setiger (Hall)
C. lepidus Hall
Tropidoleptus carinatus (Conrad)
"Spirifer" mucronatus (Conrad)
"*S.*" *tullius* Hall
"*S.*" *audaculus* Conrad
Vitulina pustulosa Hall
Athyris spiriferoides (Eaton)
Nuculites oblongatus Conrad
Liopteria cf. *conradi* Hall
Pleurtomaria (Euryzone) ilys Hall
Greenops boothi (Green)
Echinocaris?



Photograph by Bradford Willard

Figure 43. **Centerfield coral reef in highway cut, west side Brodhead Creek, Monroe County. Bedding nearly horizontal; note honeycomb texture of rock due to weathering out of large cup corals.**

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* *Vitulina* was collected on the east side of Brodhead Creek immediately below beds with Tully affinities, but was not proved to be in place. Cooper (personal communication) finds it high in the Hamilton group at Port Jervis, N. Y. He believes it to be Portland Point there. (1938).

The *Ludlowville facies* takes up about 570 feet of the middle Mahantango formation on Brodhead Creek. The base is a mass of corals in brown, rather finely sandly, calcareous shale, thickly bedded. The top cannot be separated clearly from beds of Moscow age. The coralline zone occurs in the lower part of the Ludlowville from at least as far east as Monroe County westward. This is the zone which I. C. White (228) mistakenly called Tully. Its position, physical character and fauna correlate it with the Centerfield limestone of New York so that it is here designated as the *Centerfield coral zone* (252) Figure 43. Although this appellation implies correlation, it indicates also that it is not a true limestone. It has been identified as far west as northern Lebanon County or eastern Dauphin County and is probably present in the Hamilton on the Susquehanna; but beyond that river it has not been found. Unlike the Paleozoic reefs described by Grabau (106), this one is not a true limestone, but rather a shale replete with corals and other organisms, many of them reef-builders. Its reef origin, nevertheless, must have been very similar to those of Grabau.

The Centerfield coral zone is by far the most fossiliferous portion of the eastern Hamilton and as such it has correlative value. The fauna obtained from road cuts along Brodhead Creek north of Stroudsburg is:

Receptaculites? sp.
Streptelasma rectum (Hall)
Zaphrentis prolifica Billings
Z. simplex Hall
Z. sp.
Aulacophyllum sp.
Craspidophyllum archiaci (Billings)
Ceratopora jacksoni Grabau
Syringopora maclurei Billings
Favosites hamiltoniae Hall
F. clausus Rominger
Corals, undet.
Crinoid, undet.
Crinoidea columnals
Hederella? sp.
Monticulipora sp.
Fenestella bisteriata Hall and Simpson
F. laevinodonta? Hall
F. sp.
Thamniscus sp.
Bryoza, undet.
Stropheodonta demissa (Conrad)
Leptostrophia perplana (Conrad)
Chonetes mucronatus Hall
Productella spinulicosta Hall
Dalmanella sp.
Rhipidomella vanuxemi Hall
Camarotoechia sp.
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linnaeus)
"*Spirifer*" *angustus* Hall
"*S.*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *audaculus* (Conrad)
"*S.*" *sculptilis* Hall
"*S.*" *divaricatus* Hall
Elytha fimbriata (Conrad)
Vitulina pustulosa Hall
Athyris spiriferoides (Eaton)
Brachiopod, undet.
Aviculopecten sp.
Modiomorpha concentrica (Conrad)
Glyptodesma erectum (Conrad)
Actinopteria sp.
Turbo sp.
Greenops boothi (Green)
Phacops rana (Green)
P. sp.
Plantae, fragments

The remaining beds of Ludlowville age above the coral reef are, in the east, a succession of medium-grained to coarse, dark gray sandstones and interbedded shale. Some 180 feet above the reef is a prominent storm-roller zone. This feature has been recognized for many miles westward from Monroe County and with the coral zone is useful for correlation in the field. Fossils are abundant in the Ludlowville above the reef, though not so common as in that zone.

In the Schuylkill Valley in the vicinity of Auburn and near Deer Lake, a composite Ludlowville fauna rich in pelecypods includes:

Aulopora sp.
Corals, indet.
Ancyrocrinus bulbosus Hall
Crinoidea, columnals
Bryozoa, indet.
Discina?
Leptostrophia perplana (Conrad)
Stropheodonta sp.
Chonetes coronatus (Conrad)
C. scitulus Hall
C. lepidus Hall
Dalmanella cf. *lenticularis* (Vanuxem)
Liorhynchus sp.
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *acuminatus* (Conrad)
"*S.*" *audaculus* (Conrad)
"*S.*" cf. *audaculus* (Conrad)
Orthonota undulata (Conrad)
Grammysia arcuata (Conrad)
G. cf. *arcuata* (Conrad)
G. magna Hall
G. cf. *nodocosta* Hall
G. sp.
Nucula bellistriata (Conrad)
N. cf. *bellistriata* (Conrad)
N. lirata (Conrad)
N. corbuliformis Hall
Nuculites triqueter Conrad
N. oblongatus Conrad
N. sp.
Palaeoneilo fecunda Hall
P. emarginata (Conrad)
P. cf. *maxima* (Conrad)
P. constricta (Conrad)
P. sp.
Megambonia sp.
Pterinopecten sp.
Mytilarca (Plethomytilus) oviformis (Conrad)
Modiomorpha constricta (Conrad)
M. cf. constricta (Conrad)
Goniophora rugosa (?) (Conrad)
G. hamiltonensis Hall
G. sp.
Cypricardella tenuistriata Hall
Paracyclas elliptica Hall
Schizodus sp.
Pelecypoda, indet.
Pleurotomaria?
Bellerophon (Bucanopsis) leda Hall
B. cf. *leda* Hall
B. sp.
Hormotoma (Murchisonia) n. sp.
Loxonema cf. *bellona* Hall
Platyceras (Orthonychia) conicum Hall
Coleolus cf. *tenuicinctus* Hall
Gastropod, indet.
Orthoceras subulatum Hall
O. cf. *exile* (Hall)
O. constrictum Vanuxem
O. sp.
Spyroceras crotalum (Hall)
Bactrites cf. *aciculum* Hall
Homolonotus dekayi (Green)
Trilobite, indet.

Beds of *Skaneateles* age occupy about 500 feet of the lower Mahantango north of Stroudsburg in Monroe County. Dark gray to nearly black sandstone makes up its lowest beds which are transitional with the Marcellus. Above them comes in fine, dark gray, shaly sandstone. A zone of *Phacops* was found 140 feet above the lowest beds assignable on paleontologic data to the Mahantango, but organisms are seldom plentiful. In the upper part north of Stroudsburg were found:

Zaphrentis cf. *simplex* Hall
Aulopora sp.
Ceratopora cf. *jacksoni* Grabau
Crinoidea, columnals
Fenestella sp.
Leptostrophia perplana (Conrad)
Chonetes sp.
Camarotoechia cf. *prolifica* Hall
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" sp.
Ambocoelia umbonata (Conrad)
Athyris spiriferoides (Eaton)
Nucula bellistriata (Conrad)
Pterinea flabellum (Conrad)
Platyceras auriculatum Hall
Phacops sp.

In Monroe County and likewise on the Lehigh in Carbon County, the *Berwyn* and *Delphi* members of the New York Skaneateles seem to be present; on the Schuylkill they were quite certainly identified.

There, the 475-500 feet of Skaneateles is split into three, perhaps four members. The highest 50 feet of dark gray, fine, shaly sandstone carries in its base:

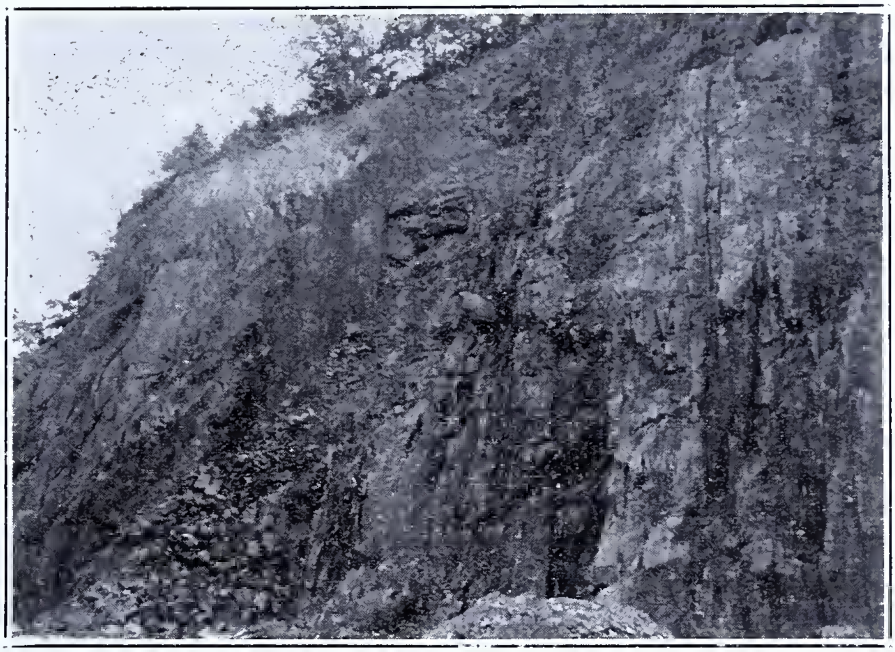
Crinoidea, columnals
Bryozoa, indet.
Leptostrophia perplana (Conrad)
Chonetes cf. *coronatus* (Conrad)
C. scitulus Conrad
Camarotoechia prolifica Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
Vitulina pustulosa Hall
Brachiopod, indet.
Orthonota undulata Conrad
Nucula sp.
Nuculites oblongatus Conrad
Bellerophon sp.
Orthoceras sp.
Homalonotus dekayi (Green)
Taonurus sp.

The *Vitulina pustulosa* is common and is believed to delimit the base of the thin upper member, the Berwyn, separating it from some 350 feet of dark shale and sandy beds below, which suggest the Delphi. Near the base of this member is 60 feet of light gray, medium coarse, buff- or brown-weathering, partly cross-bedded, flaggy sandstone. It carries a meager faunule at the Schuylkill; and is correlated with the Fort Hunter sandstone of more western sections. It carries:

Stropheodonta demissa (Conrad)
S. n. sp.
Schuchertella variabilis Prosser
Chonetes cf. *setiger* (Hall)
C. lepidus Hall
"*Spirifer*" *mucronatus* (Conrad)
Nyassa?
Buchiola?

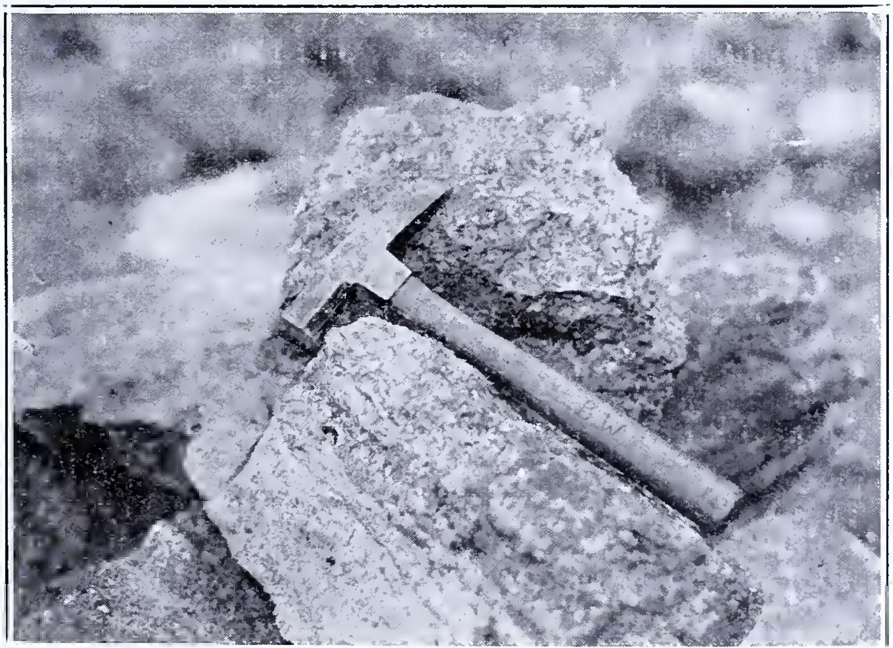
The *Mottville* has been reported (Willard and Cleaves, 257) in the Lehigh Valley at the base of the Skaneateles as a shale in whose midst is a lentil of crinoidal limestone. Its identification is doubtful.

Continuing westward, at the Susquehanna Valley, the several facies of the Mahantango of eastern Pennsylvania are no longer so clearly defined; but, upon paleontologic evidence, it is still possible to determine their approximate limits, though corroborative lithologic detail is lacking. At Rockville on the Susquehanna the Hamilton section is seen in a series of quarries which commence in the Marcellus and run up well into beds of Ludlowville age. Complementary data obtained across the river in an abandoned quarry and in numerous cuts fill in the section and show the concealed uppermost Mahantango to be soft, gray, brown-weathering shale. The remainder of the section is composed almost entirely of coarse sandstone and some conglomerate containing white quartz pebbles as much as 2 inches in diameter. The beds are dark to light gray, brown-weathering, usually fossiliferous, particularly in the higher part. This thick sandstone is the *Montebello member* or *facies* which dominates the Hamilton over much of the lower Susquehanna and Juniata Valleys. The base of the Montebello sandstone at Rockville grows finer, shalier, but contains the *Fort Hunter member* (type locality), here a very hard, dark gray, rusty-weathering sandstone, five or six feet thick, exposed in the southernmost quarry. Its meager fauna is dominated by many *Leptostrophia perplana* valves.



Photograph by George H. Ashley

Figure 44. Montebello sandstone beds standing approximately vertical, northernmost quarry, Rockville, Dauphin County.



Photograph by Bradford Willard

Figure 45. Conglomerate in the Montebello sandstone, northernmost quarry, Rockville, Dauphin County.

Fort Hunter faunule

Leptostrophia perplana (Conrad)
Rhipidomella sp.
Tropidoleptus carinatus (Conrad)
Chonetes coronatus (Conrad)
"*Spirifer*" *granulosus* (Conrad)

Where the basal Hamilton passes over into the Marcellus shale, *Toanurus* may be common. The section at Rockville exposes about 865 feet of beds which are nearly equally divided below the concealed topmost shale between those with Ludlowville and those with Skaneateles affinities. The Ludlowville-Skaneateles separation is based upon faunal data. Vague links to the Colgate member of New York have been recognized here. The faunules at Rockville, first published by Willard and Cleaves (257), were later revised by Willard (242) as follows:

Moscow facies. Not exposed at Rockville. Across the river it carries a distinctive faunule including *Ambocoelia umbonata* and *Vitulina pustulosa* overlain by Tully shale.

Ludlowville facies

Corals, undet.
Crinoidea, columnals
Hederella sp.
Fenestella sp.
Bryozoa undet.
Leptostrophia perplana (Conrad)
Stropheodonta inequistriata (Conrad)
Schuchertella variabilis Prosser
Chonetes mucronatus Hall
C. coronatus (Conrad)
Productella spinulicosta Hall
Rhipidomella leucosia Hall
Camarotoechia congregata (Conrad)
C. prolifica Hall
C. cf. *prolifica* Hall
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linnaeus)
Newberria sp. nov.
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *angustus* Hall
"*S.*" cf. *angustus* Hall
"*S.*" *sculptilis* Hall
"*S.*" *audaculus* (Conrad)
Vitulina pustulosa Hall
Athyris spiriferoides (Eaton)
Nuculites oblongatus Conrad
N. sp.
Pterinea flabellum (Conrad)
Aviculopecten cf. *princeps* (Conrad)
A. faciculatus Hall
Pleurotomaria sulcomarginata Conrad
P. sp.
Gastropod, indet.
Trilobite, indet.
Elymacaris sp. nov.
Taonurus sp.
Plant fragments.

Skaneateles facies

Zaphrentis prolifica (?) Billings
Crinoidea, columnals
Bryozoa, undet.
Chonetes coronatus (Conrad)
Rhipidomella vanuxemi Hall
R. sp.
Camarotoechia prolifica Hall
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linnaeus)
"*Spirifer*" *granulosus* (Conrad)
"*S.*" *audaculas* (Conrad)
Paracyclas lirata (Conrad)
Bellerophon sp.
Tentaculites bellulus Hall
Orthoceras sp.
Bactrites aciculum Hall
Plantae, undet.

At Barnetts Mill southeast of New Bloomfield in Perry County, a truly remarkable faunal assembly was obtained from shale at the top of the Mahantango formation immediately under the Tully:

Zaphrentis sp.
Aulopora sp.
Ceratopora jacksoni Grabau
Megistocrinus sp.
Crinoidea, columnals
Fenestella emaciata Hall
Cystodictya (Stictopora) cf. *incisurata* Hall
Pholidops cf. areolata (Hall)
P. hamiltoniae Hall

Stropheodonta (Douvillina) *inequistriata* (Conrad)
S. concava Hall
Leptaena rhomboidalis (Wilckens)
Chonetes cf. *mucronatus* Hall
C. lepidus Hall
C. cf. *vicinus* (Castelnau)
C. coronatus (Conrad)
C. scitulus Hall
Strophalosia truncata Hall
Productella spinulicosta Hall
Rhipidomella vanuxemi Hall
Dalmanella cf. *lenticularis* (Vanuxem)
Camarotoechia congregata (Conrad)
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linnaeus)
Cyrtina hamiltonensis Hall
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" cf. *granulosus* (Conrad)
"*S.*" *sculptilis* Hall
"*S.*" *tullius* Hall
Elytha fimbriata (Conrad)
Ambocoelia praeumbona Hall
A. umbonata Conrad
Necleospira concinna Hall
Anoplotheca cf. *camilla* (Hall)
Vitulina pustulosa Hall
Solemya (Janeia) vestusa (?) Meek
Nucula bellistriata (Conrad)
Nuculites oblongatus Conrad
N. cf. *triqueter* Conrad
N. sp.
Palaeoneilo fecunda Hall
P. clarkei Prosser
P. constricta Conrad
P. plana Hall
P. emarginata (Conrad)
P. cf. *tenuistriata* Hall
Aviculopecten ornatus Hall
Modiomorpha sp.
Cypricardella bellistriata (Conrad)
Cypricardinia indenta (Conrad)
Pleurotomaria (Bembexia) sulcomarginata Conrad
P. (Gyroma) capillaria Conrad
P. (Trepospira) rotalia Hall
Platyceras cf. *erectum* Hall
Loxonema hamiltoniae Hall
Bellerophon (Bucanopsis) leda Hall
Cyrtolites (Cyrtonella) mitella Hall
Diaphorostoma lineatum (Conrad)
Hyolithes aclis Hall
Styliolina fissurella Hall
Orthoceras subulatum Hall
O. cf. *subulatum* Hall
O. aulax Hall
Spyrooceras nuntium Hall
S. cf. *nuntium* Hall
Proëtus rowi (Green)
Phacops rana (Green)
Greenops boothi (Green)
G. sp.
Schizodiscus antecrenulus Cleaves
Esteria (?)
Ostracoda, sp. undet.
Spore cases ?

It is in this neighborhood that the upper part of the beds of Ludlowville age contains what may be the equivalent of the Deep Run shale of New York. This correlation is based not only upon stratigraphic position, but upon the abundance of large *Tropidoleptus carinatus*. The fauna collected from the dark shale on Board Run, northeastern Perry County is:

Crinoidea, columnals
Bryozoa, indet.
Orbiculoidea, sp.
Chonetes coronatus (Conrad)
C. scitulus Hall
C. cf. *vicinus* (Castelnau)
C. lepidus Hall
Productella dumosa Hall
Rhipidomella leucosia Hall
R. vanuxemi Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *angustus* Hall
"*S.*" *audaculus* Conrad
Orthonota undulata Conrad
Grammysia arcuata (Conrad)
Nucula bellistriata (Conrad)
Nuculites oblongatus Conrad
Leptodesma rogersi Hall
Pterinopecten undosus Hall
Modiomorpha concentrica (Conrad)
Pleurotomaria (Bembexia) cf. *sulcomarginata* Conrad
P. (Gyroma) capillaria Conrad
Bellerophon (Bucanopsis) leda Hall
Tentaculites bellulus Hall
Orthoceras sp.
Bactrites sp.
Homalonotus dekayi (Green)
Phacops cf. *rana* (Green)
Greenops boothi (Green)

Tracing the Hamilton group through the Susquehanna and Juniata valleys, the massive Montebello sandstone noted at Rockville dies out and is totally displaced by rocks of entirely different lithology, dominantly shale, indivisible into component formations and members save on faunal aspect. I described this type and named it the Mahantango formation (242) and have already quoted my original description, Chapter IV. The criteria which I deduced for separating the Mahantango roughly into parts equivalent to the Moscow, Ludlowville and Skaneateles formations of New York and which I published during my studies of the Hamilton group in Pennsylvania are as follows (242, pp. 211-213)

> The Skaneateles faunal facies may be recognized commonly by the association in the lower Mahantango of many examples of *Adolfia audacula* and *Pleurotomaria sulcomarginata*, often in whole beds to the exclusion of most other forms. *Spirifer granulosus* is commonly present, as is, also *Tropidoleptus carinatus*. The *Adolfia* and the *Pleurotomaria* tend to recur at higher levels, where considerable thicknesses of sandstone are developed. Perhaps the Skaneateles fauna can best be defined negatively by saying it is deficient in pelecypods, most gastropods, and arthropods, and is, thereby, set off from the overlying Ludlowville facies. Where the Montebello sandstone is present, its base is commonly coincident with the earliest Skaneateles fossils.
>
> The lower third of the Mahantango formation in the easternmost sections approximates the lithology of the Skaneateles of eastern Pennsylvania in that it is dark gray, brown-weathering, sandy shale, but it is practically barren. Where recognized throughout Northumberland, Perry, Dauphin, Snyder and Juniata counties, the beds which carry the Skaneateles fauna occupy, roughly, the lower third of the Mahantango formation, which in this region is dominated by the Montebello sandstone phase.......... .... In Huntingdon County the Skaneateles faunal facies appears in dark shale or gnarly sandstone. It has not been found in northern Fulton County, either because the beds which should carry it are concealed, or because, in the region of Knobsville and Hustontown .... non-marine beds constitute practically the entire Mahantango. It is found in doubtfully separable beds in southern Fulton County, where the lithology varies from gnarly sandstone to dark shale, although sandy beds are perhaps a trifle more common than in higher parts of the sections.
>
> The middle portion of the Mahantango formation contains fossils assignable to the Ludlowville faunal facies. Usually, the beds which carry these organisms are a little less sandy than those which are of Skaneateles age, except in those sections where the Montebello sandstone phase of the Mahantango dominates. In most of the sections the Ludlowville fossils are found in alternating, finely sandy shale and gray sandstones, which may become so flaggy, or even submassive in a few instances, as to produce small ridges. These sandstones, particularly well developed in Fulton and Huntingdon counties, carry recurrent Skaneateles species mingled with the Ludlowville organisms. Generally, the Ludlowville fossils range through between one-half and two-thirds of the entire Mahantango formation. In Perry and Dauphin counties the upper half of the Montebello sandstone phase is Ludlowville in age, and distinctive faunal assemblages persist there just as Skaneateles faunules occur in the lower half.
>
> The Ludlowville facies is characterized by occasional bryzoan beds, abundance of *Leptostrophia perplana*, *Schuchertella variabilis*, and several species of *Chonetes*, *Spirifer*, and *Camarotoechia*. Large numbers of pelecypods and gastropods, usually with a sprinkling of trilobites plus or minus other arthropods, are found. *Taonurus* sp. is universally present. *Vitulina pustulosa* is quite common, as is, also, *Rhipidomella leucosia*. *Tropidoleptus carinatus* (large and small varieties), a large variety of *Chonetes coronatus*, and *Spirifer sculptilis* occur and recur in zones throughout the succession. Except for *Liorhynchus limitare*, most common

in the Marcellus and rare in the Ludlowville, all species of this genus so far found have been associated with Ludlowville faunules. Briefly, the presence of beds of bryozoa, many examples of *Leptostrophia*, *Chonetes*, *Camarotoechia*, *Spirifer*, and abundant pelecypods and gastropods may be taken to indicate Ludlowville age.

Beds of Moscow age have been recognized near the tops of several sections, but at most they are probably seldom more than 50 to 75 feet thick, and their lithology is like the underlying Ludlowville strata. *Vitulina pustulosa* is abundant in the Ludlowville faunas, where it may constitute a fairly definite zone. It recurs near the top of the Mahantango formation. Where it and associated fossils are found above the Ludlowville facies, it is assumed that the beds are of Moscow age. In addition to *Vitulina*, these strata carry much the same assemblage as the Ludlowville, but with an important distinction. Where the Ludlowville is characterized by the presence or abundance of certain genera, as *Chonetes* (several species), pelecypods, gastropods, arthropods, and others, the Moscow faunules carry only a few of each of these. For example, the number of pelecypods from the Ludlowville faunules is seven times as great as from the Moscow, and gastropods are twelve times as plentiful. *Pleurotomaria sulcomarginata* and *Spirifer audaculus* are found rarely in the Moscow portion of the Mahantango formation, probably only as sandstone facies recurrents.

As with the Skaneateles and the Ludlowville, the Moscow facies becomes more obscure in the southwestern sections. It is best developed east of the Juniata River, is eroded across most of Juniata and Huntingdon counties, and re-appears in Fulton County, but there is so mingled with the Ludlowville that it is next to impossible to separate the two facies with any degree of certainty.

TABLE XXIII.—Hamilton fossils from the Mahantango formation

NAME	DISTRIBUTION†		
	Skaneateles	Ludlowville	Moscow
Streptelasma rectum Hall		v.r.	
Zaphrentis prolifica Billings	v.r.		
Z. simplex Hall		p	v.r.
Chaetetes sp.		v.r.	
Pleurodictyum sp. nov.		p	v.r.
Hederella sp.		v.r.	
Fenestella sp.		p	r
Lichenalia sp.		p	v.r.
Diamesopora cf. *constricta* Hall		v.r.	
Bryozoa, undet.	r	a	c
Lingula ligea Hall		v.r.	

† a = abundant, c = common, p = present, r = rare, v.r. = very rare.

Hamilton fossils from the Mahantango formation—Continued

NAME	DISTRIBUTION†		
	Skaneateles	Ludlowville	Moscow
Leptostrophia perplana (Conrad)	p	a	p
L. interstrialis (Vanuxem)	v.r.		
Stropheodonta demissa (Conrad)		p	r
S. inequistriata (Conrad)		p	
Schuchertella variabilis Prosser		c	p
Chonetes mucronatus Hall	r	a	
C. coronatus (Conrad)	p	a	p
C. scitulus Hall		a	v.r.
C. setiger (Hall)		c	p
C. lepidus Hall		c	v.r.
C. vicinus (Castlenau)		a	r
C. marylandicus Prosser	v.r.	p	v.r.
Strophalosia truncata (Hall)		v.r.	
Productella spinulicosta Hall		p	v.r.
Dalmanella lenticularis (Vanuxem)		r	
Rhipidomella vanuxemi Hall	r	v.r.	
R. leucosia Hall		c	p
R. penelope Hall		p	r
Schizophoria striatula (Schlotheim)		r	
Camarotoechia congregata (Conrad)	r	c	
C. prolifica Hall	p	c	v.r.
C. sappho Hall		v.r.	
Liorhynchus limitare (Vanuxem)		v.r.	
L. laura (Billings)		v.r.	
L. mesacostale Hall		v.r.	

† a = abundant, c = common, p = present, r = rare, v.r. = very rare.

Hamilton fossils from the Mahantango formation—Continued

Name	Distribution†		
	Skaneateles	Ludlowville	Moscow
L. multicostum Hall		v.r.	
Eunella lincklaeni Hall	v.r.		
Tropidoleptus carinatus (Conrad)	c	a	p
Atrypa recticularis (Linnaeus)	v.r.	c	p
Newberria sp. nov.	v.r.	v.r.	
Cyrtina hamiltonensis Hall	v.r.	r	r
"*Spirifer*" *mucronatus* (Conrad)	c	a	c
"*S.*" *granulosus* (Conrad)		a	p
"*S.*" *acuminatus* (Conrad)	v.r.	r	v.r.
"*S.*" *tullius* Hall		r	r
"*S.*" *angustus* Hall		r	v.r.
"*S.*" *sculptilis* Hall		a	v.r.
"*S.*" *audaculus* (Conrad)	a	a*	p*
Elytha fimbriata (Conrad)		r	r
Ambocoelia umbonata (Conrad)		c	v.r.
A. praeumbona Hall	v.r.	r	
Nucleospira concinna Hall	v.r.		
Vitulina pustulosa Hall		a	a
Athyris spiriferoides (Eaton)	v.r.	r	r
Meristella nasuta (Conrad)		v.r.	
Prothyris lanceolata Hall		v.r.	
Orthonota undulata Conrad		c	
O. parvula Hall		v.r.	
Grammysia arcuata (Conrad)		c	v.r.

† a = abundant, c = common, p = present, r = rare, v.r. = very rare.
* Recurrent in sandstone facies.

Hamilton fossils from the Mahantango formation—Continued

NAME	DISTRIBUTION†		
	Skaneateles	Ludlowville	Moscow
G. circularis Hall			v.r.
Tellinopsis subemarginata (Conrad)		r	
Nucula corbuliformis Hall		c	
N. bellistriata (Conrad)	v.r.	a	v.r.
N. lirata (Conrad)		v.r.	
N. varicosa Hall		r	
N. randalli Hall		r	
Nuculites oblongatus Conrad		p	
N. cuneiformis Conrad		v.r.	
N. triqueter Conrad		c	r
Palaeoneilo plana Hall	v.r.	r	
P. emarginata (Conrad)		p	v.r.
P. tenuistriata Hall		v.r.	v.r.
Leda diversa Hall		r	v.r.
L. rostellata (Conrad)		v.r.	
Pterinea flabellum (Conrad)	v.r.	p	
Leptodesma rogersi Hall		p	v.r.
Actinopteria boydi (Conrad)		v.r.	
Nyassa cf. *recta* Hall		v.r.	
Aviculopecten princeps (Conrad)		r	
A. exactus Hall			v.r.
A. faciculatus Hall		v.r.	
Lyriopecten interradiatus (?) Hall	v.r.		
Modiomorpha concentrica (Conrad)		c	v.r.
M. subalata (Conrad)			v.r.

† a = abundant, c = common, p = present, r = rare, v.r. = very rare.

Hamilton fossils from the Mahantango formation—Continued

Name	Distribution†		
	Skaneateles	Ludlowville	Moscow
M. mytiloides (Conrad)	v.r.	v.r.	v.r.
Goniophora hamiltonensis Hall		v.r.	
Cypricardella bellistriata (Conrad)		p	v.r.
Cypricardinia indenta (Conrad)		r	
Paracyclas lirata (Conrad)	v.r.	r	
Pleurotomaria sulcomarginata (Conrad)	a	c*	v.r.*
P. capillaria Conrad		v.r.	
Bellerophon leda Hall		c	
B. patulus Hall		p	
B. crenistria Hall		r	
Cyrtolites mitella Hall		p	
Macrochilus hamiltoniae Hall		v.r.	
Loxonema hamiltoniae Hall	v.r.	c	
Platyceras erectum Hall	v.r.	r	
Platyostoma euomphaloides Conrad		v.r.	
Styliolina fissurella (Hall)		v.r.	
Tentaculites bellulus Hall	c	a	p
Coleolus tenuicinctus Hall		p	
Orthoceras subulatum Hall		v.r.	
O. constrictum Vanuxem	v.r.	r	
O. telamon Hall	v.r.		
Gomphoceras pingue Hall		v.r.	
Bactrites aciculum (Hall)	v.r.	v.r.	v.r.

† a = abundant, c = common, p = present, r = rare, v.r. = very rare.
* Recurrent in sandstone facies.

Hamilton fossils from the Mahantango formation—Continued

Name	Distribution†		
	Skaneateles	Ludlowville	Moscow
Agoniatites expansus (Vanuxem)		r	
Homalonotus dekayi (Green)	r	c	v.r.
Phacops rana (Green)		c	r
Greenops boothi (Green)	v.r.	c	r
Ostracoda, undet.			r
Echinocaris punctata (Hall)		v.r.	
E. sp. nov.		r	
Tropidocaris sp. nov.		v.r.	
Phyllocarida, undet.	v.r.	p	
Ostracoderm plates, undet.	v.r.	v.r.	
Taonurus sp.		a	p
Plantae (land plants)	r	c	v.r.
Fucoids	v.r.	v.r.	

† a = abundant, c = common, p= present, r = rare, v.r.= very rare.

To complete the picture of the Hamilton group in Pennsylvania, save for details of the Montebello and related Marcellus sandstones, reserved for especial treatment subsequently, we must turn now to the region of the Allegheny Front which from central Pennsylvania sweeps in a long curve southwest and south into Maryland by way of Bedford County. The Hamilton group in this section is made up of the Mahantango and Marcellus formations as in central Pennsylvania, but there are lithic variations and faunal anomalies that deserve notice. These can be transcribed almost unaltered from my previous conclusions on the Middle Devonian of this region (246).

The prominent escarpment, designated the Allegheny Front, enters the State from Maryland through Somerset and Bedford Counties and trends north and northeast to and across Lycoming County where it fast loses its definition. In front of this escarpment, and parallel or concentric to it, runs the Devonian, with a few isolated outliers east of the principal band. (See figures 6, 37.) The Hamilton is mostly valley-forming shale, but occasional sandstones produce minor ridges. Because of the weak character of the Middle Devonian throughout the region bordering the "Front," because of the lack of folding, and because of glacial drift and outwash in the northern sections, exposures are usually inferior.

All along the Allegheny Front the upper Hamilton is assignable to the Mahantango formation, although the entire sequence as recognized in central Pennsylvania may not be present. Thus, in the northwestern sections, the Moscow, Ludlowville and Skaneateles faunal facies are known, but these are less obvious toward the south. In Bedford County lithic subdivisions have been distinguished. The Mahantango formation probably has an average thickness of 1,000 feet. Exact measurements are usually unobtainable because of poor sections. It attains its maximum of 1,300 to 1,400 feet in the south. In general the Mahantango is composed of dark gray, often sandy shale and fine, platy, brown-weathering sandstones. Some thin limestones or coquinites have been found (Figure 39) and also an occasional black shale of Marcellus type with recurrent Marcellus fossils. The formation generally weathers to chips and slivers in characteristic Mahantango style. Mahantango facies fossils are plentiful, chiefly in the middle part. These and lack of any large proportion of fissile, black shale set the formation off from the Marcellus. Throughout the region of the "Front" the Mahantango rests conformably on the Marcellus and is nearly always followed by Tully limestone.

In Bedford County the Mahantango formation is subdivided:

	Feet
c. Upper shale member*	343
b. Middle sandstone member	182
a. Lower shale member	850

The upper shale unit is olive or gray, sandy shale with thin sandstones, and limestone lenses locally developed. Fossils are commonly abundant. The median sandstone crops out in full at Chaneysville, a village in southern Bedford County. It is a hard, olive-gray, brown-weathering, massive to platy sandstone with plenty of fossils from this locality. It is entirely distinct from the Montebello sandstone of the south central sections (Susquehanna and Juniata valleys). The lower shale member is brown-weathering, dark gray, sandy shale which contains some platy sandstone, but is rarely well exposed and has provided few fossils. These Mahantango members in the south interfinger mutually and lose their identity northward. The median sandstone gradually splits up and dies out, and the whole passes over into fairly uniform Mahantango lithology. The following faunules illustrate the paleontologic nature of these members:

Top of upper shale near Schellsburg, Bedford County

Leptostrophia perplana (Conrad)
Stropheodonta demissa (Conrad)
Schuchertella variablis Prosser
Chonetes lepidus Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
Ambocoelia umbonata (Conrad)

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* In my paper "Hamilton group along the Allegheny Front" (246), I designated these as the Frame, Chaneysville and Gander Run members. These names are of only local value.

Black limestone from middle of upper shale in bed of Raystown Branch 4 miles west of Manns Choice, Bedford County (Fig. 39)

Bryozoa, undet.
Leptostrophia perplana (Conrad)
Chonetes mucronatus Hall
C. coronatus (Conrad)
C. lepidus Hall
Rhipidomella vanuxemi (Conrad)
Tropidoleptus carniatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
Palaeoneilo plana Hall
Modiomorpha concentrica (Conrad)
Paracyclas lirata (Conrad)
Pleurotomaria capillaria Conrad
Bellerophon leda Hall
Diaphorestoma sp.
Homalonotus dekayi (Green)

Base of the upper shale, southcentral Bedford County

Crinoidea, columnals
Leptostrophia perplana (Conrad)
Chonetes mucronatus Hall
C. coronatus (Conrad)
C. lepidus Hall
Tropidoleptus carinatus (Conrad)
Cyrtina hamiltonensis Hall
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *angustus* (Conrad)
Grammysia arcuata (Conrad)
Nucula bellistriata (Conrad)
N. sp.
Palaeoneilo plana Hall
Pterinea flabellum (Conrad)
Liopteria sp.
Paracycles tenuis Hall
Cyrtolites pileolus Hall (?)
Macrochilus sp.
Euomphalus sp.
Coleolus tenuicinctus Hall
Phacops sp.
Mesothyra sp.
Taonurus sp.

Composite of middle sandstone, Chaneysville, Bedford County

Crinoidea, columnals
Chonetes coronatus (Conrad)
C. scitulus Hall
C. lepidus Hall
C. vicinus (Castelnau)
Eunella lincklaeni Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *angustus* Hall (?)
"*S.*" *audaculus* (Conrad)
Nucula variocosa Hall
Pterinea flabellum (Conrad)
Modiomorpha concentrica (Conrad)
Pelecypoda, indet.
Pleurotomaria sulcomarginata Conrad
Cyrtolites pileolus Hall
Plantae, fragments

Lower shale near Saxton, Bedford County

Crinoidea, columnals
Fenestella sp.
Chonetes coronatus (Conrad)
C. scitulus Hall
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *audaculus* (Conrad)
Pelecypoda, indet.
Platyceras erectum Hall
Phacops, sp.

In the above, note particularly the occurrence of *Leptostrophia perplana* (Conrad) in the upper shale unit. It appears to be a fairly characteristic fossil. The middle sandstone member actually shows zones of fossils not brought out in the composite fauna listed. In the lower part occur many specimens of *Chonetes*, and "*Spirifer*" *mucronatus* (Conrad) is found in the highest part of this member. In its middle beds *Tropidoleptus carinatus* (Conrad) abounds. The sandstone facies elements of the Mahantango previously mentioned for central Pennsylvania occur in this member. Most of the Mahantango faunules from Bedford County are thought to be more or less closely allied with the Ludlowville of central Pennsylvania rather than with other faunal facies of the formation. The median sandstone splits in northern Bedford County with either a shale or thin limestone coming in between the components. Beyond, in Blair County, the three members are doubtfully recognized. The sandstones which Butts reported in his Altoona section (22) may in part represent the one at Chaneysville.

In Huntingdon County are many highly fossiliferous exposures of the Mahantango, particularly in the neighborhood of the borough of Huntingdon. There the Mahantango formation is divisible lithologically as follows:

		Feet
e.	Upper shale	90
d.	Upper sandstone	80
c.	Middle shale	580
b.	Lower sandstone	25
a.	Lower shale	290

Neither sandstone b nor d has been successfully matched with the one at Chaneysville, but they may tie in with those in Butts's section. In the middle shale, c, abundant fossils occur:

Middle Mahantango, shale c, Huntingdon, Huntingdon County

Zaphrentis prolifica
Ceratopora sp.
Crinoidea, columnals
Lichenalia sp.
Bryozoa, undet.
Chonetes setiger (Hall)
Camarotoechia prolifica Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *angustus* Hall
Ambocoelia umbonata (Conrad)
Vitulina pustulosa Hall
Tellinopsis subemarginata (Conrad)
Nucula corbuliformis Hall
Nuculites sp.
Palaeoneilo plana Hall
P. sp.
Pleurotomaria sulcomarginata Conrad
P. capillaria Conrad
P. sp.
Bellerophon sp.
Orthoceras sp.
Spyroceras crotalum (Hall)
Homalonotus dekayi (Green)
Phacops rana (Green)
Phyllocarid undet. (?)
Taonurus sp.

The higher sandstone, d, is separated by shaly beds, e, from the base of the Portage. This shale contains a faunule which differs from the upper shale unit in Bedford County. Rather, these fossils are to be correlated with faunules from the top of the Mahantango in Centre and Lycoming Counties. Apparently, it is a later faunnule than that in the upper shale in Bedford County whose nearest correlate at Huntingdon is found in the fossils of the upper sandstone which carries *Leptostrophia perplana* (Conrad), absent from the highest shale.

Top of Mahantango, shale e, Huntingdon, Huntingdon County

Ceratopora intermedia (Nicholson)
Crinoidea, columnals
Chonetes setiger (Hall)
C. sp.
Rhipidomella sp.
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
Grammysia arcuata (Conrad)
Nucula sp.
Nuculites sp.
Liopteria conradi Hall
Actinopteria decussata Hall
Taonurus sp.

In the middle Mahantango shale of the Huntingdon area Marcellus conditions seem occasionally to have recurred. In a quarry at the north side of Huntingdon, a black shale interbed yielded the following assemblage:

Marcellus recurrent, quarry north of Huntingdon

Liorhynchus limitare (Vanuxem)
Nucula corbuliformis Hall
Loxonema hamiltoniae Hall
Styliolina fissurella (Hall)
Orthoceras telamon Hall

In Centre County the Mahantango is usually concealed. An exposure of the top of the formation directly beneath the Tully limestone in Bald Eagle Valley yielded fossils which differ from the highest shale fossils in Bedford County and at the same time suggest the youngest shale faunule at Huntingdon. This Centre County faunule is the only one discovered along the Allegheny Front with *Vitulina pustulosa* Hall present at the top of the Mahantango. The importance of this lies in the fact that this brachiopod; as will be remembered, is characteristically common at the top of the Moscow facies in the east. The faunnule is:

Topmost Mahantango, Bald Eagle Valley, Centre County

Zaphrentis simplex Hall
Ceratopora sp.
Crinoidea, columnals
Fenestella sp.
Bryozoa, undet.
Leptostrophia perplana var. *alternata* Clarke and Swartz
Chonetes vicinus (Castelnau)
C. sp.
Strophalosia truncata (Hall)
Camarotoechia sp.
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linnaeus)
"*Spirifer*" *mucronatus* (Conrad)
Elytha fimbriata (Conrad)
Vitulina pustulosa Hall
Brachiopod, undet.
Nucula bellistriata (Conrad)
Actinopteria sp.
Cypricardella bellistriata (Conrad)
Loxonema hamiltoniae Hall
Styliolina fissurella (Hall)
Phacops sp.

Clinton County has furnishd no good Mahantango sections. In the closely folded western half of Mifflin County most of the Mahantango has been eroded. Lycoming County has supplied generally indifferent exposures. The upper Mahantango beds underlying the Tully limestone on Oak Run north of Pennsdale consist of gray, brown-weathering shale and whitish, clayey shale and carry a faunule similar to the highest Manhantango fossil assemblages in Centre and Huntingdon counties, but differing strongly from the highest shale faunule in Bedford County. Recurrent Marcellus elements are apparent, and, in the midst of the beds is a black shale of a truly Marcellus lithic aspect.

Recurrent Marcellus faunule near top of Mahantango formation, on Oak Run, Lycoming County

Crinoidea, columnals
Liorhynchus limitare (Vanuxem)
Styliolina fissurella (Hall)
Plantae, fragments

Top of Mahantango formation, Oak Run, Lycoming County

Zaphrentis simplex Hall
Aulopora sp.
Ceratopora sp.
Crinoidea, columnals
Fenestella sp.
Lichanalia sp.
Bryozoa, undet.
Orbiculoidea sp.
Leptostrophia perplana var. *alternata* Clarke and Swartz
Stropheodonta inequistriata (Conrad)
Chonetes mucronatus Hall
C. coronatus (Conrad)
Rhipidomella vanuxemi Hall
Atrypa reticularis (Linnaeus)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *tullius* Hall
Ambocoelia umbonata (Conrad)
Nucula sp.
Actinopteria sp.
Pelecyopoda indet.
Styliolina fissurella (Hall)
Homalonotus dekayi (Green)
Phacops rana (Green)
Dalmanites sp.

MONTEBELLO AND OTHER MIDDLE DEVONIAN SANDSTONES

At this point a digression is necessary to consider rather fully the Montebello sandstone of the Manhantango and the still older but analogous ones of the Marcellus. The discussion of the latter sandstones, because of their close similarity to the Montebello, was postponed when I took up the Marcellus. The whole may now be conveniently considered at one time.

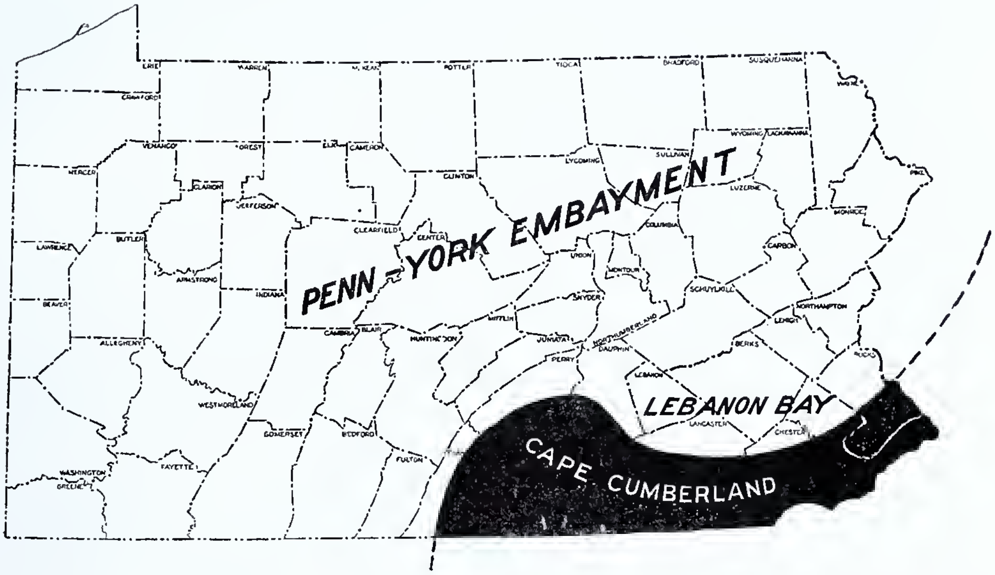

Figure 46. **Paleogeographic map of Middle Devonian time in Pennsylvania showing the supposed extent of the Penn-York embayment.**

Stratigraphic History

Origin of the sandstones. I mentioned in the preceding chapter the *Marcellus sandstones* among that formation's divisions in central Pennsylvania, that is, the lower Susquehanna and Juniata valleys, and noted that the formation consists of an upper and a lower black shale of nearly identical character, separated by two sandstones. The sequence is:

Mahanoy black shale
Mexico sandstone
Turkey Ridge sandstone
Shamokin black shale

Since the origin of the shales is presumably that ascribed to such deposits elsewhere, attention may be directed to the sandstones, the *Mexico* and *Turkey Ridge,* and to the later *Montebello* sandstone. Mention also may be conveniently made at this time of the Knobsville continental phase found in Fulton County.

The sandstones vary considerably in thickness. The Montebello, Mexico and Turkey Ridge, as illustrated approximately, Figures 40, and 47, thin away from the same central region. It is at once apparent that in central Pennsylvania the Hamilton and Marcellus show irregularities in type and rate of sedimentation, which though local in distribution and of relatively short duration, are significant. Variations of this sort are practically unknown in eastern Pennsylvania, and are elsewhere developed only to a minor extent in the sandstone member of the Hamilton at Chaneysville in Bedford County and in the thin, local lenses of sandstone north thereof at Huntingdon and in the Altoona section elucidated by Butts (22).

To explain these abnormalities, I assumed the sandstones were deposited so near the coast that sedimentation was strongly influenced by terrestrial conditions. Local variations from fine to coarse, and from fresh water to marine, may occur, particularly off the mouths of rivers, if one supposes the region to have been relatively unstable.

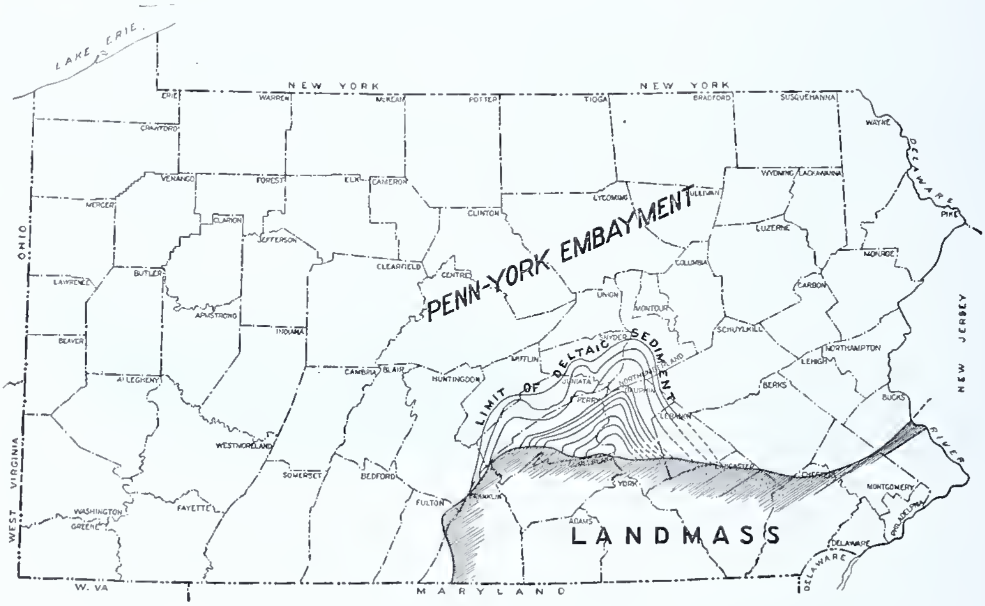

***Figure 47.* Isopach map of Montebello sandstone; interval 100 feet, approximate limit of sandstone distribution at zero (outermost) line. The Marcellus sandstones have a nearly identical distribution.**

My assumption is that the Hamilton shoreline passed in an irregular peninsular or arc, its convex side to the north, from central Lebanon County, on the east, across Dauphin, Cumberland and southeastern Franklin counties, into Maryland. East of Lebanon County a broad embayment was produced by a reëntrant of the coastline which curved to the southeast. Throughout eastern Pennsylvania there was marked regularity in Hamilton and Marcellus sedimentation uninfluenced by coastal conditions, due to remoteness of the land. West of Lebanon, deltaic sediments are thought to have been built out at at least two points, reaching north or northwestward into the sea. The larger of these loci of deltaic sedimentation centered in Perry and Dauphin counties where the Marcellus and Montebello sandstones accumulated; the other in the vicinity of Knobsville in northeastern Fulton County, produced red beds. A few years ago I tried to explain coastal conditions during Chemung time and attempted to trace the early Chemung shoreline across Pennsylvania from the northeastern counties to the southcentral border (see Chapter VIII).

I offered a demonstration that certain delta lobes developed on the seacoast in Chemung time. Our Middle Devonian sediments have what appear to be the forerunners of some of the Chemung delta lobes

The two marine sandstones of the Marcellus, the Turkey Ridge and Mexico, have nearly coincidental areal distribution and thin away from the same center. Therefore their origin appears to have been similar, and they may be discussed as a unit. The thickest portion is in the region of convergence of Juniata, Snyder, Northumberland, Dauphin and Perry counties. They thin away rapidly northward, but less suddenly to the northeast; and, westward, they continue into western Juniata County, showing in that direction their greatest extension. The exceptionally thick section near McCoysville is accounted for by its having originated nearer shore than those immediately adjacent thereto. Judging from the areal distribution and the direction of thinning, one may assume that the source of these sands lay somewhere in the region of northern or central Dauphin County. As additional proof of such an observation, there is a gradual, though not marked, decrease in coarseness of texture from the thicker toward the thinner sections. The Perry, Dauphin and Schuylkill county geologic maps and the 1931 State map show that the lower Devonian is absent across Dauphin County north of Blue Mountain, but is present east and west thereof. This I have confirmed and Dr. A. B. Cleaves has checked it in his studies of the Oriskany and Dr. Swartz for the Helderberg (Chapters III and II). Not only are the highest Silurian, the Oriskany and the Helderberg absent, but the Onondaga and the lower Marcellus as well. The only Marcellus recognized atthe Susquehanna is a black shale about 50 feet thick, correlated with the Mahanoy or highest member. It underlies beds of Skaneateles age, including the Fort Hunter. This black shale probably rests upon the Bloosmburg red beds, but the contact is today concealed. It is conceivable that the pre-Marcellus Devonian once extended all across this gap, and was later eroded from or perhaps in part faulted out in central Dauphin County. That these early Devonian formations once crossed the gap is assumed chiefly because of their full development to the east in Schuylkill and to the west in Perry County. The following discussion of happenings may be deduced.

Somewhere about the end of Onondagan time, marine deposition stopped in the region of central Dauphin County. Such a cessation may be attributed to gentle, local movement, which elevated the region off to the south, and extended in lessening degrees northward, well into the Susquehanna and Juniata valleys. There, the thin sandstone often found above the Onondaga may represent a brief interval of sub-aerial exposure. Resubmergence to the north followed, allowing the sea to return and lay down the lower Marcellus black shale, the Shamokin member, but this probably never extended into western Dauphin County, as no trace of it is there known. Rather, erosion set in to the south, so that by middle Marcellus time, coarse sediments spread northward to become the heavy-bedded Turkey Ridge sandstone of evident deltaic origin. The Turkey Ridge and the Oriskany are in many respects strikingly similar lithologically. The latter may have been the source rock for much or all of the former. The Turkey Ridge can be thought of as merely Oriskany reworked, their principal dissimilarities being the finer texture, better sorting, firmer cementation, and total barrenness of the Turkey Ridge member. The Onondaga and Helderberg, calcareous in the main, could supply no appreciable amount of reworked residue. What, if any, the Silurian system may have contributed in clastic matter to the Turkey Ridge, is undetermined, for no one knows how far south the Lower Devonian formations may have extended as a protective cover to the older system. If there were here a delta produced by a stream of appreciable size, such a stream must surely have flowed over older rocks to the south, unless one assumed a pronounced elevation near the shore, a movement for which no structural evidence has been obtained. Erosion must have been rapid. Relief suffered reduction, and the coarse heavy-bedded Turkey Ridge sandstone soon yielded place to the finer, thin-bedded Mexico sandstone, and it in turn was displaced with return of the sea by the upper, black shale member of the Marcellus, the Mahanoy. It was this last which transgressed into central Dauphin County as the only Marcellus now known there. Its southward migration implies a slight settling of the area. Such conditions partially explain the exceptional westward thinning of the Marcellus between Schuylkill and Dauphin counties.

The *Montebello* sandstone facies* of the Mahantango formation of the Hamilton group spread over the uppermost Marcellus black shale. Its distribution and character imply a more or less close reënactment of those Marcellus scenes which caused the laying down of the Turkey Ridge and Mexico members. The sandstone thins with comparative abruptness northward, eastward and westward (figure 47). The texture grows finer away from the source of supply, the region of Dauphin and Perry counties and southward. The bedding, too, changes from massive to the south to flaggy, northward. There is no sign of an unconformity at the base of the sandstone, for its grades down into the black Marcellus shale in Dauphin, Lebanon and eastern Perry counties. Presumably, uplift was slowly resumed, and rejuvenated streams renewed their delta-forming after the local transgression into the black Mahanoy shale member. In the basal Montebello, there is, locally, the heavy Fort Hunter sandstone. The succeeding lower third of the Montebello in Dauphin County carries considerable dark shale and rather fine dark sandstone, whereas beds of the same age in northern Perry County are nearly all coarse.

During the Sixteenth International Geological Congress (201), 1933, I had the pleasure of showing the Rockville section to Prof. Armand Renier of Belgium. Professor Renier noted what he considered to be the roots of land plants *in situ* in this shalier, lower Montebello. Beds carrying these carbonized fragments alternate with undoubted marine strata with Montebello facies invertebrates. If this observation be true, it appears that the lower Montebello at Rockville is an alternation of marine and non-marine, possibly produced under estuarine conditions.

But the upper half of the Rockville section is all typically marine without land plants in place. It is nearly all coarse sandstone plus a few shaly beds replete in *Taonurus* markings. If the dark, shalier, lower part be considered estuarine with alternation of marine and fresh-water conditions, the fresh-water beds may have dominated at first, but gradually gave place to the marine environment of Ludlowville time. As a corollary, those lower Montebello beds which probably spread the farthest from their source of supply, are composed of comparatively coarse sandstone and are all marine. This is attributed to sorting by currents and waves off shore in shallow water. Simultaneously, the shalier marine and fresh-water beds formed near shore where sorting was less complete, perhaps where too much mud came in to be completely removed. The area may even have been more or less protected by configurations of the near-by coast.

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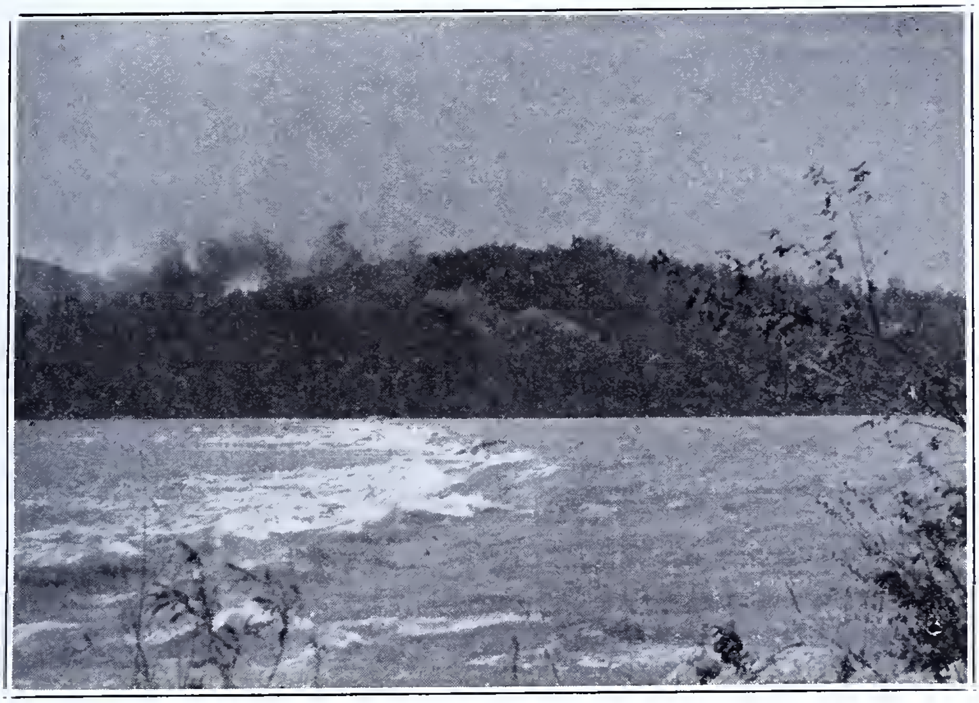
* Name originally used by E. W. Claypole (72).



Photograph by George H. Ashley

Figure 48. **A ledge of Montebello sandstone produces "falls" on the Juniata River at Half Falls Mountain, Perry County.**

The distribution shown in figure 47 indicates that the Marcellus and Montebello sandstones are spread more to the west than to the east of their locus of origin. This distribution conforms to that noted for the Chemung delta lobes aforementioned and fully described in Chapter VIII. This distribution or distortion is attributed to the action of marine currents, produced by a clockwise rotation of the Devonian epeiric sea water which may be supposed to have produced a current flowing southwestward along the shore of Appalachia.

The *Knobsville continental beds* are found in the region of Knobsville, their type locality, in northeastern Fulton County. They are a phase of the Mahantango formation, and are made up of red and green beds devoid of marine organic remains save for a few poorly preserved specimens of dubious identity which occur at the margins of the deposit where it passes over into marine strata. This passage is gradual and determines the Hamilton age of the lower part of the Knobsville. The continental beds thicken eastward until lost through erosion toward the Franklin County line. It is enough to remark that they represent the landward portion of a rather small delta which began during early, and continued through later Mahantango time. This phenomenon will be recalled in the discussion of the Devonian geologic history, particularly in comparing the Knobsville beds with conditions observed in the Middle and Upper Devonian of north-central New Jersey and their bearing upon Pennsylvania.

Hamilton Summary

The Hamilton succession in eastern Pennsylvania is similar to that worked out by Cooper in central New York, but the divisions are less clearly defined. Westward and southwestward across central Pennsylvania, the New York affinities and similarities grow obscure. New subdivisions not recognized in the east appear, and local, lithologic anomalies occupy large parts of the Hamilton succession to the elimination of all else. Thus, in the Susquehanna Valley, the Moscow, Ludlowville and Skaneateles equivalents are only roughly deliminated faunally. The name Montebello sandstone is long in use for the great mass of Hamilton sandstone in the lower Susquehanna and Juniata valleys. Elsewhere, the monotonous succession of post-Marcellus shales broken only by thin sandstone lenses has been designated the Mahantango formation.

Still farther to the southwest, the Hamilton group is even less differentiated. Local divisions show in the Mahantango. Here there seems good faunal reason for suspecting that no beds of Moscow age are present. Throughout, the Hamilton group exhibits, despite its lithologic variations, a close faunal unity. Its major divisions above the Marcellus, when not lithologically distinct, are differentiated, not upon the presence or absence of particular genera or species, but upon the relative abundance or the proportional distribution of the faunas among the several classes of invertebrates.

CHAPTER VI.

THE UPPER DEVONIAN, SENECAN STAGE

THE PORTAGE GROUP

History and Definition

The base of the Upper Devonian is established largely upon the appearance of an immigrant fauna *(Hypothyridina)* which characterizes the base of the Upper Devonian in Eurasia and reached the Appalachian province possibly via the Gulf of Mexico at the beginning of Portage time (Tully limestone). The deposition of detrital sediments continued, however, with only gradual change. In central New York, where the *Portage group* was defined, it consists of alternating dark shales and flaggy sandstones. Westward it grades entirely into black shales, but toward the east passes into flaggy fossiliferous sandstone and finally into massive sandstone without fossils (Oneonta) and in the eastern face of the Catskills into red beds (Schuchert and Dunbar 185).

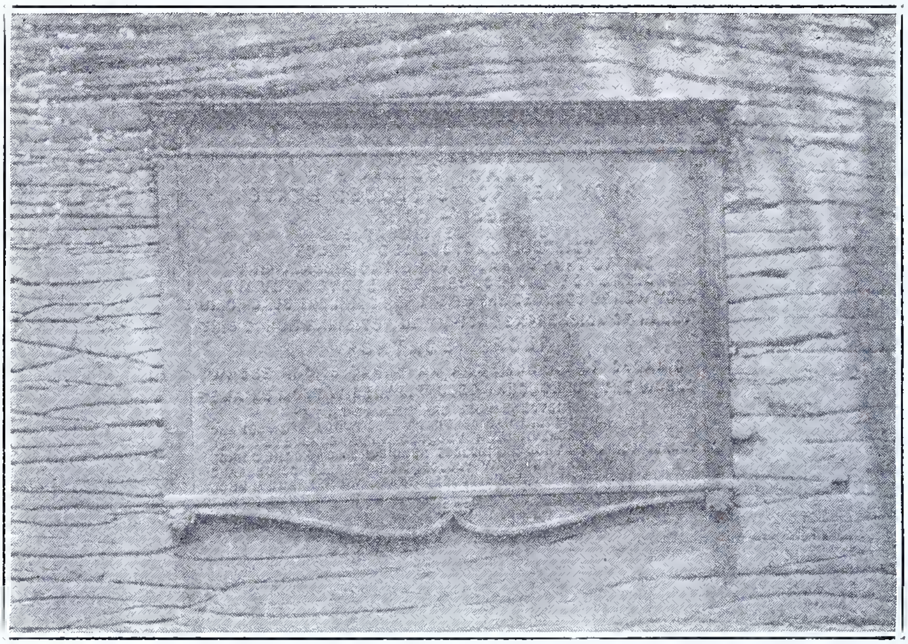
In Pennsylvania the term Portage group is now and here used to include all marine strata intervening between the superjacent Chemung (recognized by the appearance of *"Spirifer" disjunctus*) or its continental equivalent, the Shohola formation, and the subjacent Hamilton. Therefore, the present use of Portage is somewhat more inclusive than common, since it embraces beds assignable to the Tully, and the Genesee group and later. The nomenclatorial sequence which has been adopted is partly that proposed by Butts (22), with later modifications and additions derived chiefly from my own studies in the Susquehanna Valley and eastward and published in my separate account of the Portage in Pennsylvania as follows (245):

PORTAGE GROUP

- Fort Littleton formation
  - Parkhead member
  - Brallier member
  - Trimmers Rock member
  - Losh Run member
  - Harrell member

- Rush formation
  - Burket member
  - Tully member

In this sequence, I designate two formations, separated at the Harrell-Burket contact. The individual members are closely allied, interfingering horizontally and vertically. It should be observsed, and will be fully explained later, that the Brallier shale is the off-shore equivalent of the Trimmers Rock sandstone. The Harrell is inseparable by any sharp line of contact from the Brallier, and the Burket and Tully intergrade. The Losh Run, too, fades into adjacent members. The name Fort Littleton formation is derived from the village in northeastern Fulton County, and Rush from Rush Township, Northumberland County.

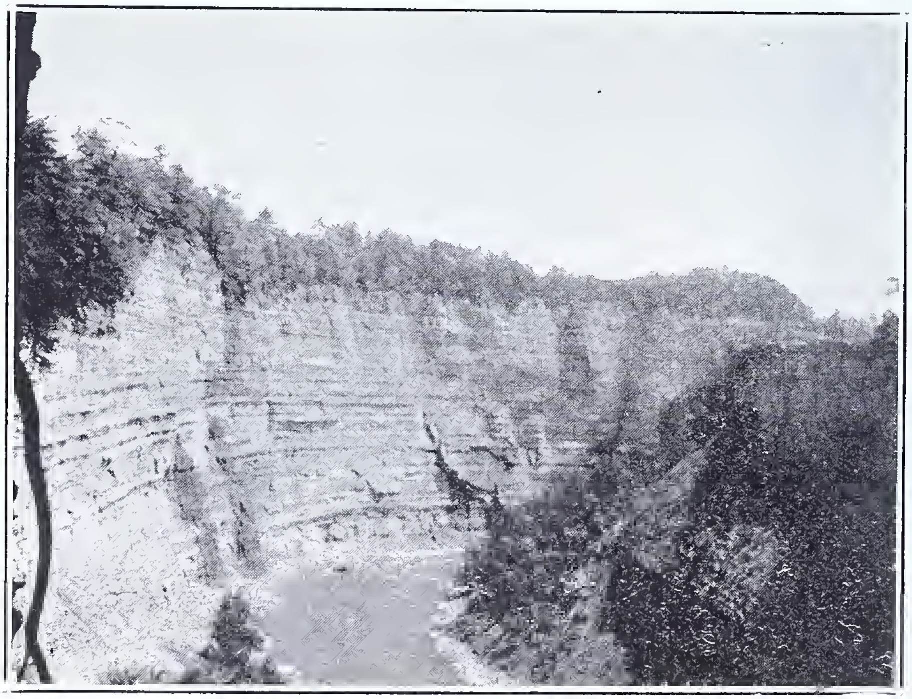


Photograph by Bradford Willard

Figure 49. **Tablet in Letchworth Park, N. Y., commemorating the early work of James Hall. The inscription reads:**

JAMES HALL
State Geologist of New York
1837-1898

Established in this Fourth Geological District, the classification of a large part of the New York system of geological formations which gave enduring repute to the geology of New York. This gorge exhibits the typical expression of Hall's PORTAGE GROUP whose rocks carry an assemblage of organic remains widely diffused throughout the world.



Photograph by Bradford Willard

Figure 50. **View of gorge of Genesee River, Letchwork Park, New York, showing "Portage flags."**

NEW YORK

It is unnecessary to set down a long dissertation on the origin of the use of the term Portage. A few facts will suffice: Proposed by Hall in 1840 for beds of post-Gardeau age (110), it now is recognized in New York to embrace the strata from the Genesee group (as defined by Chadwick, 44) to the Chemung. If Chadwick is correct, it appears that this Portage today is considerably restricted in western New York, since he would place the Chemung-Portage contact below the Gardeau. In western New York, the Portage is characterized by a succession of dark shales, more or less a recurrent Genesee facies, and lighter, sandier to flaggy beds. The nomial sequence need not concern us. Carried eastward to the region of Ithaca, there is a striking facies alteration. As the dark shales above the Genesee group disappear, arenaceous elements dominate. In the Ithaca region the Upper Devonian sequence below the Chemung is summarized thus:

Enfield shale
Ithaca shale
Sherburne sandstone
Genesee shale
Tully limestone

Farther east these units change still more and assume a continental facies in the upper part, the Oneonta sandstone. The entire Portage is thought to become non-marine in the Catskills.

These lithologic variations are accompanied by corresponding faunal facies changes. In the western, shaly facies, the fossils belong to the Naples fauna characterized by such small pelecypods as *Lunulicardium, Ontaria, Cardiomorpha, Paracardium* and *Buchiola*, the cephalopods *Manticoceras, Probeloceras* and *Bactrites* and swarms of pteropods. The sandy facies carries the strongly Hamilton-Ithaca fauna. Brachiopods are abundant including *Leptostrophia, Atrypa, Chonetes. Cyrtina "Spirifer";* and large pelecypods assignable to *Actinopteria. Grammysia, Modiomorpha,* etc. abound together with several genera of gastropods, cephalopods and trilobites. The continental facies contains a few plants and fresh-water "clams."

In New York the term Genesee has taken on the value of a group designation and includes four divisions. At the base of these is the Geneseo black shale, the original "Genesee" of Vanuxem, 1842 (218). Its sparse fauna includes inarticulate brachiopods, a few small pelecypods, pteropods and an occasional cephalopod. It appears to be a forerunner of the Naples fauna.

The Tully formation in New York has recently been reviewed by Cooper and Williams (80). They report it to be a "thin wedge of sediments lying disconformably on the Hamilton formation." They recognize three members, with *Hypothyridina* characteristic of the middle one. Limestone dominates in the central part of New York, but the Tully becomes an argillaceous sandstone eastward, with gradual loss of distinction among the three members until finally, Tully fossils are found mingled with an Ithaca fauna.

MARYLAND

In Maryland the term Portage was not in favor when the official nomenclature was adopted by the State Survey in 1913 (143). The beds of Portage equivalence are designated as the lower part of the Jennings formation of Upper Devonian age:

Jennings formation (lower part)
  Parkhead member
  Woodmont member
    Ithaca fauna
      Liorhynchus globuliforme zone
      Cladochonus-Reticularia laevis zone
    Naples fauna
  Genesee member

The Woodmont, 1200 to 1600 feet thick, is greenish, argillaceous and sandy shale with thin sandstones of various colors interbedded. Organisms are few. In its upper part Ithaca fossils occur, and in the lower part a Naples assemblage has been recorded. The Ithaca fossils at the top anticipate the fauna of the Parkhead member which, throughout its 400 to 600 feet of shale, sandstone and conglomerate, carries a Hamilton-like assemblage. The so-called Genesee of Maryland is black shale with a few fossils suggesting a greatly impoverished Naples fauna.

Geographically between the highly differentiated New York succession and the generalized Maryland sequence of the same age is the Portage group of Pennsylvania. It is as truly stratigraphically as geographically intermediate. It embodies some of the New York facies changes though it lacks the diversification of the western sections. Conversely, the Portage of Pennsylvania has many of the characters of the Maryland beds, but shows a more complete picture than is exposed to the south.

PENNSYLVANIA

Henry D. Rogers (177) assigned, in descending order, the names VERGENT SHALES and VERGENT FLAGS to the beds beneath his PONENT SERIES (Catskill). These he tied in successively with the "Chemung group" and "Portage flags" of New York. The correlation probably is not far off, but it is only reasonable to assume that the Chemung-Portage boundary was not properly established. The Vergent flags appears to correspond lithologically most nearly to the Brallier. The Vergent shales may embrace both Chemung sandstone and shale and Trimmers Rock sandstone. Rogers, like his successors in Lesley's Survey, never correctly distinguished the Portage from the Chemung in the east where only the former is represented by a marine facies, but he did recognize the equivalent of the New York Genesee (i. e. the present Geneseo) as the CADENT UPPER BLACK SLATE in contradistinction to the CADENT LOWER BLACK SLATE (Marcellus). His report that it contained "small and delicate fossils" suggests that he included both our present-day Burket and Harrell members under this heading. Apparently he did not know of the Tully in Pennsylvania.

The Second Survey included what they called "Tully" with the Hamilton, but probably never correctly recognized the limestone. Rather, their "Tully" was always a Hamilton coral bed and, therefore, truly interbedded with the Hamilton sandstones and shales. They may have found it on Chillisquaque Creek as "20 feet of shaly dark blue limestone, weathering ashen gray and holding many *Ambocœlia umbonata . . .*" (Lesley, 137; p. 1320). The lithology described tallies with the known Tully in this region, and the reported "*Ambocœlia*" may not improbably be *Echinocœlia ambocœlioides* Cooper and Williams. Lesley's men sometimes distinguished the Genesee as formation VIIIe, but they erred in its identification when it was recorded "2 miles above Port Jervis". In central Pennsylvania it was usually correctly recognized save when confused with the Marcellus. Ashburner's sequences in Aughwick and Hare valleys (4) indicate that he knew and distinguished lithologically what we call Harrell and Brallier members. A fauna was recognized in Huntingdon County which we would at once call Naples (*Cf.* Clarke, 59, 63).

The Portage proper (VIIIf in part) was a neglected factor save for some of the shalier occurrences. Its close lithic resemblance, to the Chemung, where dominated by sandstone in central Pennsylvania, left distinction dubious at best. Lesley's Portage fauna is clearly Naples as used today (137; p. 1363).

> On the lower Juniata in Perry County, the *Portage-Chemung* interval varies in thickness from 3800′ (3300′?) at Newport to 1100′ in Rye Township on the Susquehanna at Marysville. How much of this should be considered *Portage*, there seems no mode of determining; nor is it a matter of any great importance. So far as fossil species can settle such a question, the whole of it may be called Chemung. But at the very bottom of the mass or rather underlying it are about 200 feet of coarse black shales in which *Portage species* [i. e. Naples species] occur in sufficient abundance at most localities where their outcrops are exposed to view. But the commonest and most characteristic shell among them is in New York both a *Portage* and a *Genesee* species, *Cardiola (Avicula) speciosa*. Considering the thinness of the *Genesee* in Perry County (200′) and the black color of these shales, it seems more reasonable to assign them as an upper division to the *Genesee* and look for the *Portage* among the Chemung strata overlying them. But it is useless to do this as there seems to be no criterion at hand.

Had Lesley deleted the last sentence, the above paragraph would have been worthy of the remarks of a geologic Solomon. The final statement nearly ruins the whole thing! Of the east, where no marine Chemung occurs, Lesley said "all of the shells are of the Chemung type". Stevenson (198) after the manner of Rogers, mentioned Chemung shale and Portage flags, but made no clear distinction between them. White failed to understand the Chemung-Portage situation east of the Susquehanna (228, 229) but in Huntingdon County (230) assigned 2500 feet of beds to the Chemung (VIIIf) and Portage (VIIIe), divided into massive, gray sandstone above and yellowish, sandy shale and shaly sandstone below. Claypole (72) recognized 200 feet of black, nearly barren shale in Perry County which he correctly called Genesee VIIId (now Burket) and above this 200 feet of *Cardiola* dark shale, VIIIe, which belongs to the Harrell and perhaps in part the Brallier. The sandy Trimmers Rock above he regarded as Chemung.

Not until Williams and Kindle (265) in 1904 published their Hollowing Run and Catawissa sections was the Ithaca fauna correctly observed in central Pennsylvania. Prosser (161) had recognized it in our most eastern exposures a decade earlier and showed that I. C. White's interpretations of the Upper Devonian were quite erroneous. Of 1400 to 1600 feet of Portage in the Susquehanna Valley, Williams and Kindle recognized 200 to 400 feet of Genesee barren, dark shale, 400 to 600 feet of dark gray shale, thin-bedded, with a Naples fauna, and 600 to 1100 feet of dark gray shale and sandstone with Ithaca fossils. Their lowest member embraces our Burket, but probably contains no true Harrell, for they reported it barren. The succeeding middle member is mostly Brallier with a probable "*Reticularia lævis* zone" in the midst. These beds they called Sherburne, but without lithologic or faunal support of this implication. The highest part, the sandy beds with Ithaca fossils, is our Trimmers Rock sandstone. Williams and Kindle appear to have been unable to find any unmistakable Tully. Soon afterward, in 1906, Kindle (126) doubtfully reported Tully near Altoona. This identification both Butts (22) and I (255) have since independently substantiated as authentic.

It was in the study of the Altoona section that Butts gave us, in 1918, the first reliable foundation for much of our present interpretation of the Portage. He recorded doubtfully what later proves to be Tully, and he recognized and named the Burket, Harrell and Brallier shales. All these were included in the Portage group. His original descriptions follow:

Brallier shale	Fine-grained, siliceous shale in thick, even layers revealing their fissility on weathering. Largely wavy or dimpled laminae, some even and slaty. A few thin fine-grained sandstone layers. Fossils small and very scarce. *Buchiola retrostriata, Probeloceras lutheri, Phragmostoma natator.* Upper Portage.
Harrell shale	Dove and black fissile (paper) shale. Black at bottom to west (Burket member). Black and dove interbedded to east. *Buchiola retrostriata, Paracardium doris, Pterochania fragilis, Styliolina fissurella, Probeloceras lutheri.* Lower Portage.

He discovered "*Chonetes aurora* in 1 foot limestone at very top [of the Hamilton] (Tully?, Upper Devonian)". Since the appearance of Butts's paper, Cleaves has made unpublished studies of the Portage group in the New Bloomfield quadrangle, embracing most of eastern Perry County. He is in close accord with my findings. I myself recognized unquestioned Tully over wide areas extending from eastern Northumberland, Carbon, Schuylkill, and Perry counties west to the Allegheny Front and south to Bedford County (238, 240, 245, 247, 255). I have applied Butts's data over this same region and identified the three shales, making the Burket a separate member and probable correlate of the Geneseo rather than the basal portion of the Harrell as did Butts. With Cleaves, I recognized as Portage and subsequently named the thick Trimmers Rock sandstone in the Susquehanna and Juniata valleys. This I have since traced east to the Delaware River (245, 250). In that geographic interval much of it becomes continental in nature. The presence of another shale, named the Losh Run, was made known and it or its characteristically abundant *Reticularia lævis* occurs widely, an excellent correlation datum.

Distribution and Limits

The Portage group has a wide distribution in Pennsylvania, comparing in this respect favorably with that of the Middle Devonian. The beds enter Pike County above Matamoras as a relatively broad band which, narrowing, as dips steepen, continues west to the Susquehanna. The outcrop winds back and forth through the central region, largely in the Susquehanna Valley, then swings into a long curve, east of the Allegheny Front, to Maryland. Lesser areas are found in Bedford, Fulton, Huntingdon, Blair and western Juniata counties (Figure 51).

The lower limit of the Portage group as here used coincides with the contact between the Middle and Upper Devonian. In Europe the Middle-Upper Devonian line has been drawn beneath the "*cuboides* zone". In New York, through supposed analogy between that zone and the Tully limestone with *Hypothyridina venustula*, the Middle-Upper Devonian boundary has sometimes been placed between the Tully and Hamilton. To this designation there are dissenting opinions, and other usages have found credence and are current. Acknowledging that the question is still open, but also recognizing that its final settlement may still be a long way off, I have chosen to draw the line below the Tully. Only recently has such a separation been feasible in Pennsylvania, because the wide distribution of our Tully and its fauna has been but lately established. In the absence of the limestone over parts of the State, other distinguishing criteria are recognized in many sections.

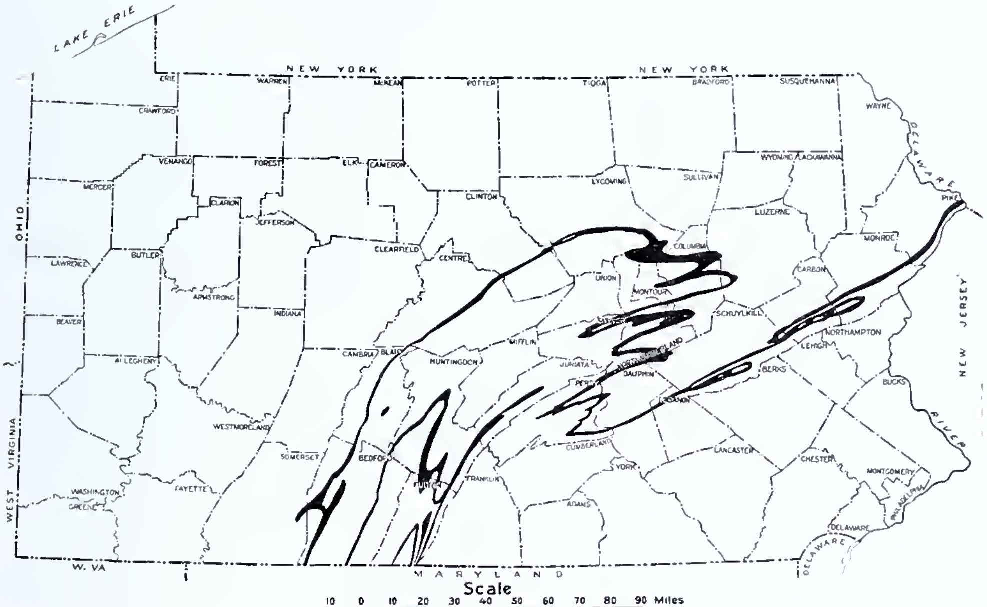


Figure 51. **Sketch map showing distribution of Portage group (exclusive of the Tully, which is shown independently in Figure 54) in Pennsylvania.**

Throughout most regions where both the Portage and Middle Devonian rocks are exposed, the top of the latter may be identified through the occurrence of *Vitulina pustulosa* with or without *"Spirifer" tullius*. These fossils are rare or absent from extreme eastern sections; but, except in the most eastern area, there is an accompanying lithologic break. The Mahantango (Hamilton) shale is overlain by beds with Tully fossils from northwestern Bedford County north and east through Lycoming County, and occurrences have been seen in Northumberland, Columbia, Luzerne, Schuylkill, Carbon, Monroe and Perry counties. In these sections the Tully limestone or shale, etc. rests on dark-gray, buff-weathering, clayey Mahantango shale. The Tully is either a massive gray or curiously banded limestone or a limy shale in most sections where the contact has been observed. Although the basal Tully is sometimes concealed, never, in the contact exposures, has a Hamilton-Tully transition been unquestionably established. The Tully may be absent, whereupon the Burket black shale rests upon the Mahantango or Moscow facies thereof; but, once more, a sharp lithic change is observed at the Middle-Upper Devonian contact. Dark-gray, clayey shale underlies fissile black beds without observed transition. The organic change is also distinct from the plentiful, often abundant, Hamilton fauna to the very meagerly populated or barren Burket beds. I have identified the Burket east to the Lehigh Valley near Lehighton and a remnant is also present in Monroe County north of Wind Gap. Its absence farther east is explained on the basis of displacement of the black shale facies by the more coarsely clastic sediments of the Trimmers Rock member and its plentiful Ithaca fauna, with or without Tully elements.

The disappearance of the Burket eastward robs us of a convenient criterion for separating the Middle from the Upper Devonian, for, the Trimmers Rock sandy beds may rest upon upper Hamilton rocks of similar lithology. A remarkable instance of separation based directly upon faunal evidence stands out. On Brodhead Creek, north of Stroudsburg, Monroe County, *Hypothryridina venustula* occurs in the basal Trimmers Rock in association with Ithaca fossils. This occurrence is thought to correlate the basal Trimmers Rock in Monroe County with the Laurens in New York. In Monroe County the *Vitulina* zone at the top of the Hamilton (Moscow formation) is not fully proved below the "Laurens", nor is such recorded farther east in Pennsylvania to the Delaware Valley. The Middle and Upper Devonian in eastern Monroe County and across Pike County, therefore, are without means of sharp separation because of elimination eastward of all known distinguishing data. The adjacent beds of Hamilton and Portage ages are of essentially like lithology, so that here, and here only, in Pennsylvania, there is no recognized hard and fast line of separation between the two. Only on the general faunal aspect may we infer which beds are Upper and which are Lower Devonian.

It must be added that, in south-central sections, though the *Vitulina* zone may be absent from the top of the Mahantango, the lithologic and faunal change is pronounced and sharp either into the Burket or, where that is absent, as in parts of Fulton County, the Harrell or Brallier. As noted, the disconformity here is probably quite comprehensive. These sections of course lack Tully limestone.

Summing up these relations from the Allegheny Front to the Delaware Valley we have:

Allegheny Front	Fulton County	Susquehanna Valley	Lehigh Valley	Brodhead Creek	Upper Delaware Valley
Tully	Brallier	Tully-Burket	Tully	"Laurens"	Trimmers Rock
————	————	Disconformity	————	———— ?	Transition
Mahantango	Mahantango	Mahantango	Moscow	Moscow	Moscow

Contrary to the lower contact of the Portage group, its upper limit is often far from well-defined. *"Spirifer" disjunctus* is common in our Chemung and later marine Devonian, but unknown from the Portage. Therefore, wherever possible the top of the Portage group is drawn beneath the lowest occurrence of this brachiopod. Throughout the region from the lower Susquehanna Valley and its North Branch west of the Anthracite Fields to the Allegheny Front, this criterion is constantly present. It is practically the sole means of differentiation in many sections; for, in general, they lack lithologic means of differentiation. Where the Trimmers Rock sandstone is succeeded by the Chemung, there is no reliable lithic change. Along the Allegheny Front where the Portage usually ends in the Brallier shale, there is a lithologic difference between it and the Chemung. But, without the supporting evidence of paleontology, it cannot be used with absolute certainty. Too often the Brallier carries sandstones and the Chemung, shales, which confuse the issue. This is particularly true in some of the splendid sections in Clinton and western Lycoming counties. Incidentally, this distinction is also vitiated in Bedford and Fulton counties where more or less of a remnant of the Parkhead sandstone of Maryland crowns the Portage group. East of the Susquehanna River, *"Spirifer" disjunctus* is unknown save in some minor occurrences in western Luzerne and west-central Dauphin counties. From central Dauphin to Port Jervis, New York, so far as I can determine, the top of the Trimmers Rock sandstone grades up into continental beds whose age may usually be demonstrated to be late Portage (236, 245, 250).

Stratigraphy

In the beginning of this chapter the history of the development of the use of the term Portage in Pennsylvania was reviewed and it was shown that formations of this age were early recognized by Rogers as the CADENT UPPER BLACK SLATE and (in part at least) the VERGENT FLAGS. Nevertheless, neither the First nor Second Surveys left a clear account of the group. There was extant no complete description of the Portage group and lists of its fossils or its surface exposures for the whole of Pennsylvania prior to 1935. In that year my "Portage group in Pennsylvania" (245) appeared following my brief notes in the Tully (238, 240). In 1937 I published a fuller account of that limestone and its fauna (255). The description which is here given is drawn largely from my writings. The earlier discussion is, however, amplified, though only slightly modified, because of findings since made or because of slight changes in point of view.

The Portage group in Pennsylvania is divisible into several units which, while their lithology and faunas may vary greatly among themselves, are nevertheless near relatives. This close affinity necessitates the grouping together under a single heading of so large a part of the Upper Devonian. While this grouping might not be applicable in New York, a close unity exists with Maryland. In Pennsylvania, intermediate between these two territories, the divisions cited are of wide geographic distribution, but not all need be expected to occur in a particular section. Their geographic ranges are not necessarily coincident, nor are their geologic ranges uniform. I repeat the succession of the Portage group in Pennsylvania:

PORTAGE GROUP

- Fort Littleton formation
  - Parkhead member
  - Brallier member*
  - Trimmers Rock member*
  - Losh Run member
  - Harrell member
- Rush formation
  - Burket member
  - Tully member

Just how far we should go in using the term formation in the above classification is questionable. There is a definite line of separation between the Burket and Harrell so that the use of the terms Fort Littleton and Rush in the sense of formations is convenient. Most of the members are fully capable of delineation on 1:62,500 scale maps. Many of the members display lateral and vertical intergradations which make a closely knit whole. The Brallier shale and the Trimmers Rock sandstone are respectively off- and on-shore equivalents. The Harrell gray shale may not be sharply distinguished from the greenish Brallier, either faunally or lithologically, at their contact. The Losh Run is merely a thin band, in some places a faunal zone, occurring chiefly in the lower part of the Trimmers Rock, but also represented in the lower Brallier.

FORT LITTLETON FORMATION

Parkhead member. The Maryland Survey recognizes the Parkhead sandstone at what in Pennsylvania is called the top of the Portage group, coming as it does directly beneath the *"Spirifer" disjunctus*-bearing basal Chemung beds. It is usually heavy sandstone with interbedded shale and conglomerate. The distinctive fauna is said to be a recurrent Hamilton facies. It is characterized by *Rhipidomella vanuxemi* Hall, *Camarotœchia congregata* var. *parkheadensis* Clarke and Swartz, *"Spirifer" mesacostalis* Hall and *"Spirifer" marcyi* var. *superstes* Clarke and Swartz. The member is known in Fulton County and doubtfully occurs in Bedford County, where the uppermost Portage bears faunal and lithic resemblance to the Maryland Parkhead. Northward, however, it rapidly loses its distinctive features and fades into the Brallier shale. Even after the disappearance of the characteristic, sandy, lithology, the fauna may persist. Thus, near Huntingdon, I listed (245) its most northerly occurrence so far discovered:

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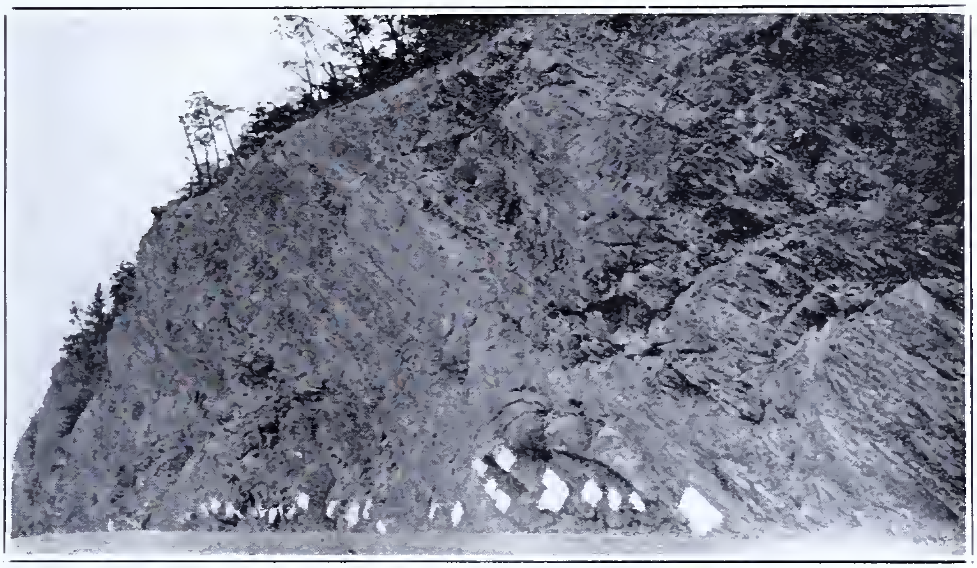
* As will develop below, the Brallier and Trimmers Rock and certain other members are more or less complementary, so that the succession here quoted need not be taken too literally in applying the law of superposition.

Parkhead faunule from uppermost Portage at Huntingdon, Huntingdon County

Crinoidea, columnals
Rhipidomella vanuxemi Hall
Camarotoechia congregata var. *parkheadensis* Clarke and Swartz
C. eximia (Hall)
Pugnax pugnus var. *altus* Calvin
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mesacostalis* Hall
"*S.*" *mesastrialis* Hall
Pleurotomaria (Gyroma) capillaria Conrad
Gastropod?



Photograph by George H. Ashley

Figure 52. **Trimmers Rock sandstone exposed on Juniata River south of Half Falls Mountain, Perry County. Note flaggy character of sandstone interrupted by zones of storm rollers.**

The Parkhead is suspected of being present eastward in Perry County. There the highest beds of the Trimmers Rock sandstone take on a chocolate hue and carry *Rhipidomella vanuxemi* Hall, *Camarotœchia congregata* var. *parkheadensis* Clarke and Swartz, *Tropidoleptus carinatus* (Conrad) and "*Spirifer*" *mesacostalis* Hall. "*Spirifer*" *marcyi* var. *superstes* Clarke and Swartz was not found here. No more easterly occurrence has been observed.

Trimmers Rock member. At some places below the Parkhead, where that is present, but forming the highest member of the Portage group over much of the Susquehanna and the Juniata valley is the Trimmers Rock member. On the Delaware River above Matamoras and thence westward into central Pennsylvania, the Portage group is dominated by this thick sandstone member. In the Susquehanna and lower Juniata valleys where it is particularly well developed, the type locality is Trimmers Rock, a prominent hill of this sandstone 1½ miles east of Newport, Perry County, along the west side of the Juniata River. The Trimmers Rock is typically greenish-gray or gray, flaggy to massive sandstone and interbedded gray shale. Rather fine in central Pennsylvania, it tends to grow coarse eastward, though probably never assumes a conglomeratic phase. Its hardness makes it a comparatively important ridge- or escarpment-maker. This character is lost as it grades westward into the Brallier shale. The Trimmers Rock is a highly fossiliferous sandstone bearing an Ithaca faunal facies indicated by the following list compiled from collections by Cleaves and me from Perry County.

Composite Trimmers Rock fauna, Juniata Valley, Perry County

(This list includes probable Parkhead faunules)

Coral, indet.
Crinoidea, columnals
Petalotrypa cf. *compressa* Ulrich
Fenestella sp.
Semicoscinium sp.
Bryozoa, indet.
Stropheodonta cf. *demissa* (Conrad)
S. maynardi Clarke and Swartz
Leptostrophia perplana var. *nervosa* (Hall)
Schuchertella sp. nov.
Chonetes lepidiformis Clarke and Swartz
Productella lachrymosa (Conrad)
P. sp.
Rhipidomella vanuxemi Hall
R. sp.
Schizophoria striatula (Schlotheim)
Camarotoechia congregata (Conrad)
Liorhynchus globuliforme (Vanuxem)
L. cf. *quadricostatum* (Vanuxem)
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linneus)
"*Spirifer*" *mesastrialis* Hall
"*S.*" *mucronatus* var. *posterus* Hall and Clarke
"*S.*" *mesacostalis* Hall
Athyris spiriferoides (Easton)
Brachiopod, indet.
Grammysia communis Hall
G. sp.
Nucula corbuliformis Hall
N. sp.
Nuculites cf. *oblongatus* Conrad
Palaeoneilo brevis Hall
Pterinea chemungensis (Conrad)
P. prora Hall
Ectodesma birostratum Hall
E. sp.
Liopteria sp.
Pelecypod, indet.
Bellerophon clarki Clarke and Swartz
B. nactoides Clarke and Swartz
Bucanopsis maeria (Conrad)
Diaphorostoma lineatum (Conrad)
Tentaculites descissus Clarke and Swartz
T. spiculus Hall

Because of the fauna and its stratigraphic position, this sandstone has been referred to as the "Ithaca" by some writers, but I am disinclined on various grounds to use the name. In Northumberland, Snyder, Juniata and Perry counties and thence into adjacent portions of surrounding areas, these strata occupy practically the entire Portage group with comparatively little shale intervening between their base and the top of the Mahantango with its Hamilton fauna. Above, the Chemung or Catskill caps the Trimmers Rock save for probably a little Parkhead in eastern Perry County. The Losh Run shale coming at or near the base of the sandstone is probably Sherburne in age, and there is no distinct Enfield. Admitting that the Trimmers Rock may be a partial equal of the Ithaca in New York, it is quite probable that a correlation may eventually be established between the Enfield and some of our shaly Portage beds. But, more probably, the Trimmers Rock is the correlate of the Enfield, the Ithaca, and a large part at least of the Sherburne.

In most sections of central Pennsylvania the Trimmers Rock sandstone is set off from the Chemung only by the occurrence of *"Spirifer" disjunctus* in the latter. Separation otherwise would be difficult from Lycoming southward. Usually the base of the Trimmers Rock can be assigned upon lithic and faunal grounds. The Losh Run and a thin remnant of the basal Brallier afford a sharp lithic contrast in the lower Susquehanna Valley, but in western Lycoming and parts of Huntingdon County, etc., there may be considerable intertonguing between the Brallier and Trimmers Rock. In the Susquehanna Valley the Losh Run begins to assume the lithology and fauna of the Trimmers Rock and so is soon lost. Eastward from the Susquehanna, the Trimmers Rock sandstone, consequently, comes to rest upon still lower shales; but the Brallier and Harrell are, like the Losh Run, almost immediately supplanted by the sandy facies with Ithaca species. Still, the sandstone continues to rest upon the black Burket shale as far as western Monroe County, where it too grows sandy and is soon lost.

Composite Trimmers Rock fauna from south-central Schuylkill County.

Aulopora sp.
Crinoidea, columnals
Fenestella sp.
Bryozoa, indet.
Lingula sp.
Stropheodonta demissa (Conrad)
Chonetes vicinus (Castelnau)
C. sp.
Rhipidomella vanuxemi Hall
R. sp.
Schizophoria striatula (Schlotheim)
Camarotoechia congregata var. *Parkheadensis* Clarke and Swartz
C. horsfordi? (Hall)
C. sp.
Liorhynchus mesacostale Hall
L. globuliforme (Vanuxem)
Tropidoleptus carinatus (Conrad)
Atrypa reticularis (Linneus)
Cyrtina hamiltonensis Hall
C. sp.
"Spirifer" mesastrialis Hall
"S." mucronatus var. *posterus* Hall and Clarke
"S." mesacostalis Hall
Grammysia sp.
Sphenotus sp.
Nucula corbuliformis Hall
N. bellistriata (Conrad)
N. sp.
Nuculites oblongatus ? Conrad
Palaeoneilo plana Hall
P. emarginata ? (Conrad)
P. tenuistriata ? Hall
Leptodesma rogersi ? Hall
L. longispinum ? Hall
L. lichas Hall
L. sociale Hall
L. sp.
Modiella pygmaea (Conrad)
Actinodesma cf. *erectum* (Conrad)
Actinopteria sp.
Schizodus sp.
Modiomorpha concentrica (Conrad)
M. sp.
Cypricardella tenuistriata (Hall)
C. sp.
Paracyclas lirata (Conrad)
P. sp.
Pterinopecten sp.
Pelecypoda, indet.
Pleurotomaria (Gyroma) capillaria Conrad
Platyceras sp.
Tentaculites spiculus Hall
T. sp. nov.
Gastropod, indet.
Trilobite, indet.
Echinocaris (?) sp. nov.
Rhinocaris columbina Clarke
Ostracoderm fragments, indet.
Plantae, fragments

With the final disappearance of the Burket eastward between Brodhead Creek and the Lehigh, the Trimmers Rock, as noted in discussing the basal Portage contact, rests directly upon the highest beds of Middle Devonian age, the Mahantango formation with its

Moscow faunal facies.* The separation is not always completely clear. Nevertheless, I cited the occurrence on Brodhead Creek in Monroe County of Tully elements mingled with the Ithaca fossils in the base of the Trimmers Rock sandstone. In this section a composite fauna from the top of the Hamilton includes:

Crinoidea, columnals
Atrypa reticularis (Linneus)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *angustus* (Conrad)
Vitulina pustulosa Hall
Grammysia arcuata (Conrad)
Cephalopod, indet.
Phacops cf. *rana* (Green)
Greenops (Cryphaeus) boothi (Green)

The Portage-Hamilton contact is not satisfactorily exposed. At the intersection of State Highways 90 and 190 south of Analomink the following faunule with Tully elements was obtained in sandstone 73 feet thick and 54 feet above the top of the supposed *Vitulina* zone of the Hamilton:

Crinoidea, columnals
Fenestella sp.
Rhipidomella vanuxemi Hall
Camarotoechia orbicularis (Hall)
C. eximia (Hall)
Liorhynchus mesacostale (Hall)
Hypothyridina venustula (Hall)
Vitulina pustulosa Hall
"*Spirifer*" *mucronatus* var. *posterus* Hall and Clarke
"*S.*" sp.
Echinocoelia ambocoelioides Cooper and Williams
Pleurotomaria (Gyroma) capillaria Conrad

The interesting and exceptional feature is, of course, *Hypothyridina*, but the general faunal aspect suggests the Laurens of eastern New York. More will be said of this unique occurrence in the comments on the Tully.

Still farther east in Pike County, the Portage-Hamilton faunal separation is increasingly difficult. The following lists illustrate this enigmatic situation.

- 1 -

Crania (?) sp.
Liorhynchus cf. *mesacostale* Hall
"*Spirifer*" *mesastrialis* Hall
Orthonota carinata Conrad
Grammysia subarcuata Hall
Palaeoneilo plana Hall
P. emarginata (Conrad)
Leda diversa Hall
Actinopteria boydi (Conrad)
Paracyclas lirata (Conrad)
Pelecypod, indet.
Gastropod, indet.
Homalonotus dekayi (Green)
Psilophyton princeps Dawson

- 2 -

Ceratopora jacksoni Grabau
Crinoidea, columnals
Bryozoa, indet.
Roemerella grandis (Vanuxem)
Lingulella planiformis (Hall)
Orbiculoidea sp.
Leptostrophia perplana (Conrad)
Stropheodonta sp.
Chonetes vicinus (Castelnau)
Rhipidomella vanuxemi Hall
Camarotoechia prolifica Hall
C. horsfordi (Hall)
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *granulosus* (Conrad)
"*S.*" *audaculus* (Conrad)
"*S.*" *augustus* Hall
Athyris cf. *cora* Hall
Aviculopecten faciculatus Hall
Paracyclas lirata (Conrad)
Pelecypod, indet.
Plantae, fragments

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* The truly facies character of the Trimmers Rock sandstone is here illustrated. Although defined as a member of the Fort Littleton formation, it is here observed to displace the eastern remnant of the Rush formation.

- 3 -

Chonetes lepidus ? Hall
Camarotoechia horsfordi (Hall)
Schizophoria striatula (Schlotheim)
"*Spirifer*" *mucronatus* (Conrad)
"*S.*" *mesastrialis* ? (Hall)
Phthonia?
Grammysia bisulcata? (Conrad)
Palaeoneilo emarginata (Conrad)
Liopteria conradi Hall
L. sp.
Nyassa arguta ? Hall
Actinopteria subdecussata Hall
A. boydi (Conrad)
A. epsilon ? Hall
Cypricardella bellistriata (Conrad)

The first of the three foregoing lists is quite certainly of pronounced Ithaca affinities; the second is a Hamilton facies from beds not far above the thick Marcellus. The third of the three lists is questionable. It might be called upper Hamilton in age, but it possesses elements leaning toward the Portage. For example, observe the pelecypods *Palaeoneilo amarginata* and *Actinopteria boydi.* The list of pelecypods in this faunule is longer than is common in the upper Hamilton beds. The rather sudden injection into the fauna of many genera of this class of organisms seems to be the only basis to differentiate the Middle and Upper Devonian in this part of the State.

The Trimmers Rock sandstone attains a maximum thickness of approximately 3000 feet in eastern Lycoming County (see Figure 65). This prominence is maintained south and east, but the member thins westward as it laps over its off-shore complement, the Brallier shale, and finally disappears from most sections on the Allegheny Front (*cf.* fig. 64). East of the Susquehanna Valley, the marine Chemung is practically unknown, for the only recognized occurrences of "*Spirifer*" *disjunctus* are in western Luzerne and west-central Dauphin counties. Instead, the Trimmers Rock grades upward into succeeding continental beds of the Catskill facies, generally of late Portage age. As such, since they are not necessarily red (they may be green or brown), they are assignable to a thin, westward remnant of the Delaware River flags of our northeastern section. This matter is fully discussed in the description of the continental Devonian, Chapter VIII.

Losh Run member. The Trimmers Rock sandstone in the Susquehanna Valley from Lycoming County on the west to Luzerne on the east, south to Perry County, and westward to Huntingdon and perhaps into Fulton County, rests upon or includes close to its base what I have called the Losh Run member. It was named for a small stream in Perry County which enters the Juniata River from the west 5 miles north of Duncannon. Locally, this member is finely sandy, but usually it is a dark-gray to brown shale which weathers rusty-brown. It breaks into blocks exhibiting an irregular, almost conchoidal fracture without regard to bedding or joints. This uniform shale maintains an average thickness of about ten feet. Besides its characteristic and distinguishing lithology, it carries a fauna encountered in no other of our Upper Devonian members. Crinoid fragments are locally abundant and *Cladochonus humilis* Clarke and Swartz (or a nearly related species) and *Recticularia laevis* (Hall) predominate. This shale is a splendid datum over a rather isolated province. Its relatively restricted geographic distribution does not embrace the

Allegheny Front where it would be of great value in determining the exact correlation of the lower part of the Brallier. One example, however, was found near Shade Valley, southeastern Huntingdon County where the Losh Run fauna occurs not far above the base of the Brallier (see Figure 65). If this is synchronous with eastern occurrences it supports the evidence that the lowest part of the Brallier in this region is the equivalent of the basal Trimmers Rock to the east. This correlation helps to tie in these two complementary members. The Losh Run member was not found east of the Susquehanna save locally on the North Branch. A more diversified fauna of Ithaca species invades it eastward. Evidently it passes into the Trimmers Rock. This faunal change is illustrated by the following list from Northumberland County:

Cladochonus humilis Clarke and Swartz
Crinoidea, columnals
Leptostrophia perplana var. *alternata* Clarke and Swartz
Douvillina sp.
Chonetes scitulus Hall
C. lepidus Hall
Rhipidomella vanuxemi Hall
Reticularia laevis (Hall)
Echinocoelia ambocoelioides (?) Cooper and Williams
Cephalopod, indet.

Even the doubtful occurrence of *Echinocoelia ambocoelioides* Cooper and Williams here is interesting, for it was found also in the Laurens faunule in Monroe County and is abundant in many Tully outcrops in Pennsylvania.

Brallier member. The Second Pennsylvania Survey recorded lithic differences among the strata between what they called "Genesee" and "Chemung." Curiously, this was the limit of their progress. Only when Butts in 1905 (19) applied to the post-"Genesee" Portage shales, the term Nunda for which he later, 1918, (22) substituted the better, local term Brallier, did systematic subdividing of the shaly phase of the Pennsylvania Portage start. Butts's original description of the succession near Altoona is of wide application. The Brallier extends along the Allegheny Front, having there a thickness of about 2,000 feet and then thins eastward into the valley of the Susquehanna, practically its eastern limit. In most exposures and where characteristically developed, the Brallier is a fine shale which has a tendency to break into thin slabs coincident to the extremely smooth bedding surfaces. Sandstone beds are not exceptionally rare, however, and many thin ones may alternate with the typical shale. The member is green, gray-green to gray. Invertebrate fossils are few, but often one finds large numbers of finely comminuted black shreds and specks of plant fragments on the bedding surfaces. Also there occurs the curious "annelid" trail *Pteridichnites biseriatus* Clarke and Swartz. Less distinctive and unnamed trails also are known. It should be observed that *Pteridichnites* has not been found in the highest part of the Brallier, nor it is recorded from the fully developed, sandy Trimmers Rock member,* and it is rarely found in the underlying Harrell shale. For these reasons it is a fair guide fossil to the Brallier. Close correlation of the Brallier is hindered by lack of fossils. The occasional stray Ithaca forms and rare occurrences of Naples elements are of little more than general application.

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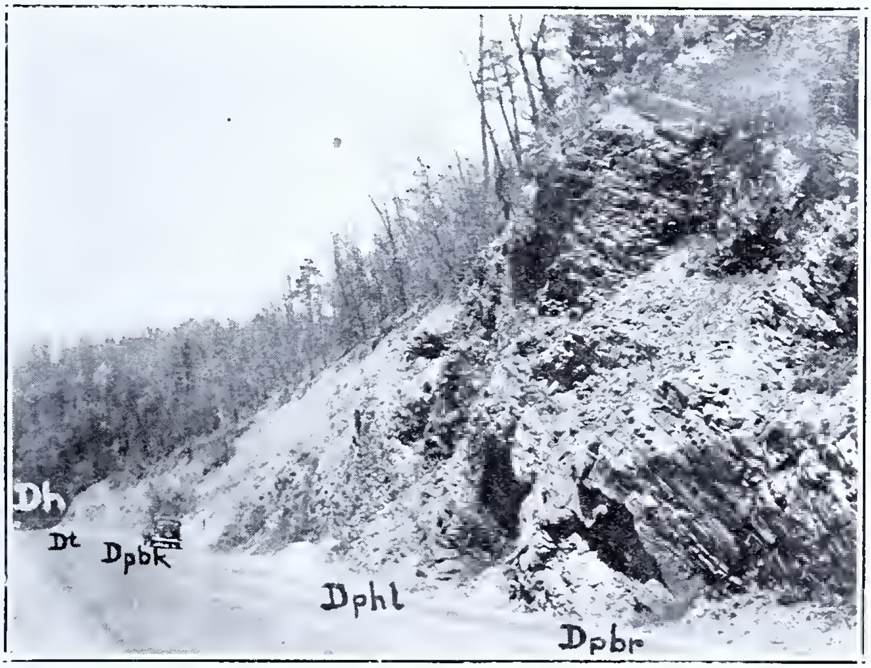
* A dubious specimen was found by me in Schuylkill County in the fall of 1937.

East of the Susquehanna River Valley, the Brallier shale has not been identified. Along that river, its best exposures are in central Pennsylvania, particularly on the tributary creek valleys in Lycoming County and southwestward into Bedford and Fulton counties. What is perhaps the easternmost typically developed exposure was discovered in cuts on State Highway 17 between Millerstown and Liverpool, Perry County. Brallier-like shale is found, however, here and there in the more eastern Trimmers Rock sandstone.



Photograph by Bradford Willard

***Figure 53.* Section along the Juniata River south of Half Falls Mountain, Perry County. The interbedded sandstone and shale at the extreme right are Brallier (Dpbr). Passing down (away from observer) the next beds are Harrell (Dphl). The automobile is parked at the top of the Burket black shale (Dpbk). At end of cut beyond car is exposed the Tully limy shale (Dt) in contact with the *Vitulina* zone at top of Mahantango shale (Dh). Opposite small, square, white signboard at the guard fence at "Dh" is top of Montebello sandstone.**

Harrell member. Beneath the Brallier is Butts's, 1918, Harrell shale. The name is here applied in a modified sence through separation from the Burket. It is thinner and faunally and lithologically different from the overlying Brallier. The Harrell is fine, dark-gray (Butts calls it ''dove'') to nearly black shale, weathering brownish to buff. Some platy beds occur. Fossils are plentiful—tiny pelecypods, schools of pteropods and coiled celphalopods—a Naples fauna.

Harrel faunule from Saltillo, Huntingdon County

Pteridichnites biseriatus Clarke and Swartz
Lunulicardium encrinitum Clarke
Pterochaenia sinuosa Clarke
P. cashaquae Clarke
P. fragilis (Hall)
P. fragilis var. nov. ?
Posidonia mesacostalis (Williams)
Ontaria sp.
Buchiola retrostriata (von Buch)
Paracardium doris Hall
Styliolina fissurella (Hall)
Coleolus sp.
Hyolithes sp.
Bactrites gracilior Clarke
Manticoceras patersoni (Hall)
M. sp.
Probeloceras lutheri (Clarke)
Cyrtoclymenia neapoiltana (Clarke)
Plantae, fragments

The wide distribution of the Harrell shale is nearly identical with that of the Brallier between the Allegheny Front and the Susquehanna Valley, east of which it practically disappears through assuming a Trimmers Rock lithology and an Ithaca fauna. New highway cuts across Weir Mountain in western Monroe County reveal a little dark shale with a few, sporadic Naples fossils below the Trimmers Rock. The thickness is fairly uniform, rarely exceeding 60 or falling below 40 feet. Such rather remarkable constancy suggests uniform, widespread conditions of sedimentation similar to those postulated, hereafter for the underlying Burket. In this it contrasts strikingly with the remaining Fort Littleton members. The widespread fauna has few variants. The following list was taken on Fiddlers Run, Northumberland County, 69 miles east from the occurrence of the preceding:

Harrell faunule, Fidders Run, Northumberland County

Ceratopora sp.
Crinoidea, columnals
Pterochaenia fragilis (Hall)
Buchiola retrostriata (von Buch)
Paracardium doris Hall
Pleurotomaria ?
Styliolina fissurella (Hall)
Probeloceras lutheri Clarke

The Harrell is included in the Fort Littleton formation upon lithic and faunal grounds. It intergrades with the Brallier, and stragglers of its Naples fauna survive in the younger beds. On the other hand, the Harrell is in much sharper contact with the Burket, for which reason I have separated them, contrary to Butts's original usage. Along the New York Central Railroad in southeastern Lycoming County where the line follows the east bank of the West Branch of the Susquehanna River below Larrys Creek Station, an excellent exposure shows these relations. Below the Losh Run shale on the Juniata River in Perry County, the here arenaceous Harrell and Brallier blend closely and must pass over eastward into the basal Trimmers Rock, but the Burket does not follow suit immediately.

RUSH FORMATION

Burket member. Because Chadwick has elevated Genesee to a group term and because of the now recognized stratigraphic succession for the lower Portage in Pennsylvania, the name Genesee is dropped. A long range correlation with the Geneseo, lowest division of the Genesee group of New York, is too hazardous. Butts (22) has proposed the name Burket for this black shale at or near the base of the Portage group. This suggestion is adopted except that he defined it as a variation or subdivision at the base of the Harrell, and I distinguish it as the upper member of the Rush formation (245), thereby setting it off distinctly from the Harrell which is placed in the Fort Littleton formation. Its distinctive lithologic and faunal character, its lack of close relationship to the Harrell and its affinity to the Tully warrant such a step. Faunal lists by the Second Survey for the "Naples" and "Genesee" in Pennsylvania indicate that the Harrell and Burket were grouped together. In Maryland the list of fossils assigned the "Genesee" indicates their adoption of a restricted use. That is, the "Genesee" of Maryland equals our Harrell to the exclusion of the Burket which, it is altogether probable, is absent in Maryland. The Burket is present at Everett, Bedford County, but only 15 miles south at Chaneysville an exposure shows the Harrell in disconformable contact with the Mahantango shale with a Hamilton faunule. This is probably the counterpart of the Maryland situation.

The Burket, like the Harrell, is thin, seldom exceeding 40 feet, usually only 20 feet. Exceptional thicknesses, as along the east bank of the Juniata in Perry County, exceed 100 feet. The Burket-Harrell contact is fairly sharp. Where the Burket rests upon beds of Hamilton age, there is an unmistakable hiatus, a feature already mentioned in describing the basal contact of the Portage group. Where the Burket is separated by Tully limestone from the top of the Middle Devonian, the black shale and limestone are clearly transitional (Figure 55), with the Hamilton-Portage break transferred to the base of the Tully.

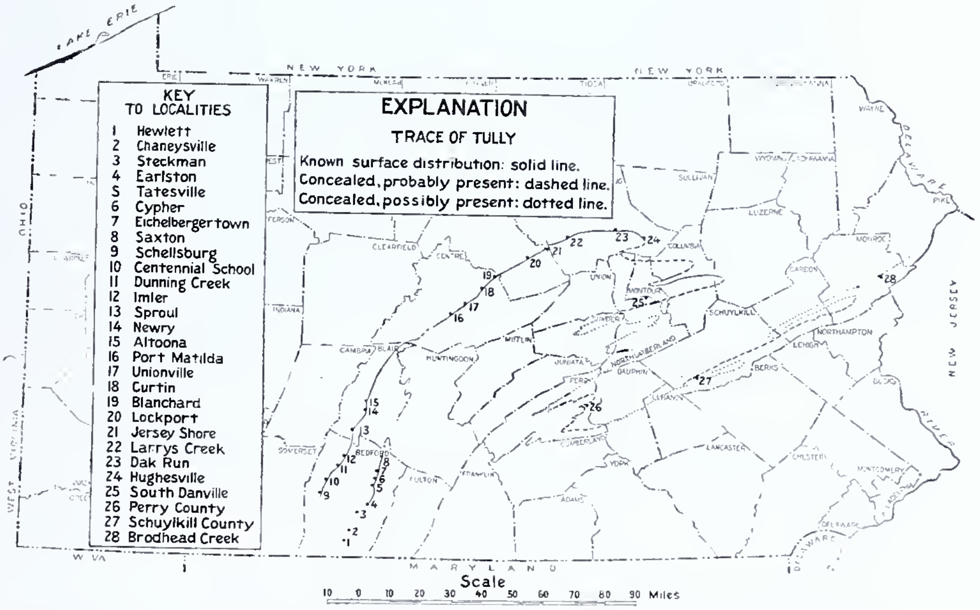
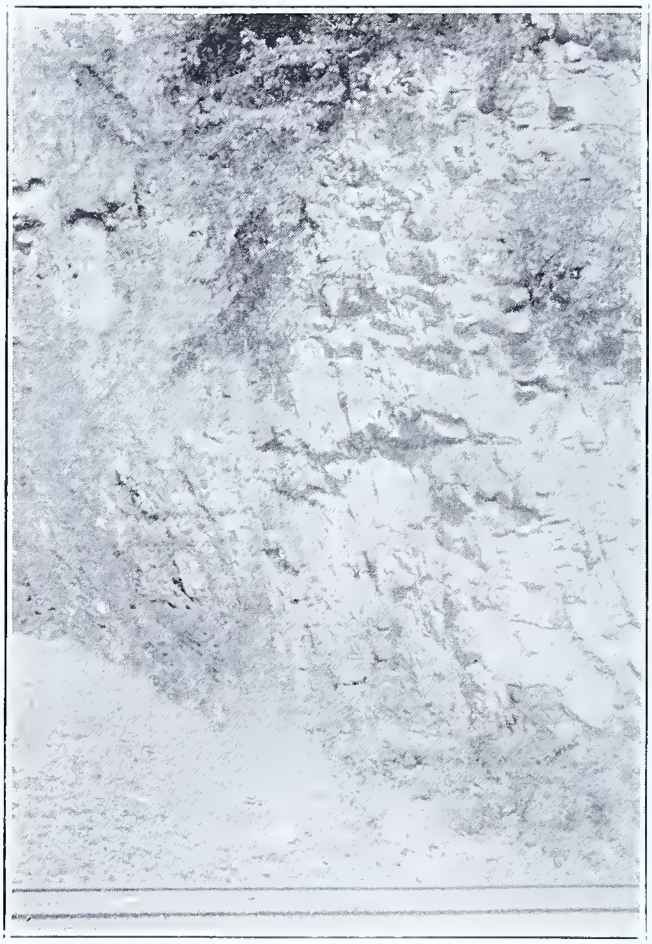


Figure 54. **Sketch map showing distribution of Tully in Pennsylvania.**

Tully member. The Second Pennsylvania Survey reported "Tully" limestone, but listed no characteristic fossils. So far as can be determined, none of their localities is true Tully. Still, they may have actually found Tully organisms, for all of their exposures cannot be rediscovered, and the original material collected is not all available for restudy.* The earliest record of the finding of a diagnostic Tully fossil in Pennsylvania (*Chonetes aurora*) appears to be that of Butts in 1918 (22). Kindle (126) in 1906 probably found this same zone, but his statement is not fully convincing. Until 1934, this record remained unique. Then (238) and subsequently, I reported Tully limestone and fossils widely distributed through much of middle Pennsylvania (255). Its known outcrop is shown in the sketch map, Figure 54.



Photograph by Bradford Willard

Figure 55. **Tully-Burket transitional contact on Susquehanna River south of Larrys Creek, Lycoming County. Black shale, left; limestone, right; hat marks transition.**

The Tully limestone, as explained above, is here taken to mark the base of the Upper Devonian. Most of its occurrences are confined to the sweep of Devonian formations which follows the curve of the Allegheny Front, between Bedford and Lycoming counties. In northeastern Bedford County, eastern Perry, east-central Northumberland, Columbia, Luzerne, Carbon and Schuylkill counties the fauna occurs, usually in shaly strata. A unique instance of Tully fossils in the base of the Trimmers Rock sandstone has been mentioned from Monroe County (locality 28). In southern Bedford County (localities 1, 2, 3 and 4) neither limestone nor fauna is known. From there to Maryland the Middle Devonian is disconformably overlain by either the nearly barren Burket black shale or the gray Harrell with its Naples fauna. In parts of Fulton County, even the greenish Brallier rests on the Mahantango (Hamilton). Sometimes the Tully is shaly in its higher beds and grades into the Burket. Where the upper Tully is more massive, the contact with the Burket is sharper, though probably everywhere transitional. The basal part of the Tully may be limestone or shale. Where the base has been observed in Pennsylvania it is in disconformity with beds of Hamilton age.

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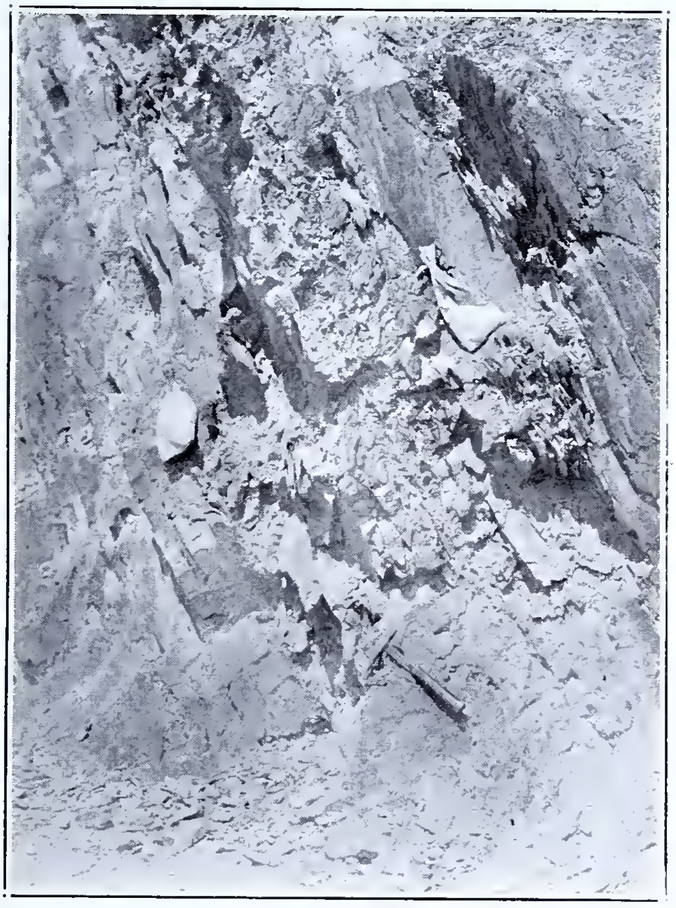
* I have personally reviewed the collections at the Philadelphia Academy of Natural Sciences with only negative results.



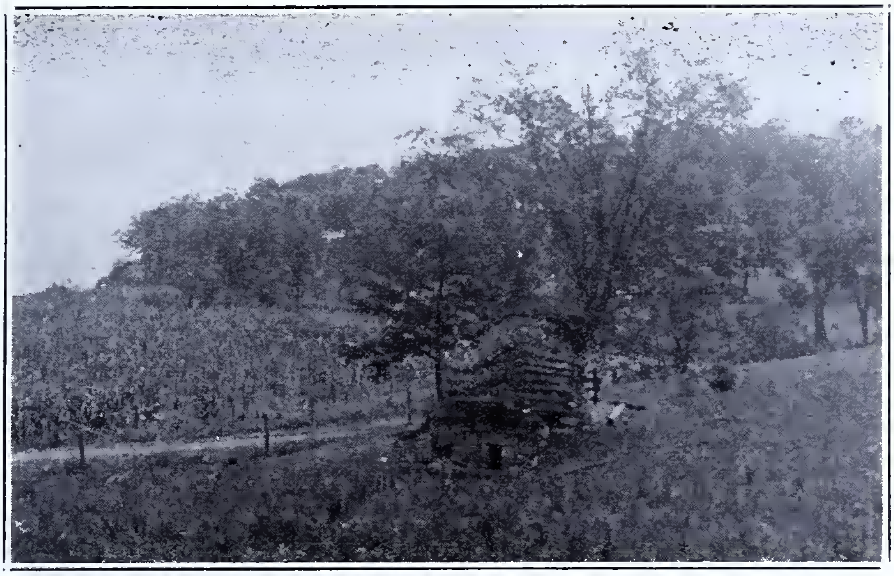
Photograph by Bradford Willard

Figure 56. **Tully limestone exposed in road cut east of Eichelbergertown, Bedford County. White bags mark limits of the limestone; at left is top of Hamilton shale; Burket black shale shows at right.**

At locality 5 (Tatesville) along the Huntingdon and Broad Top Railroad, a cut exposes two limestones, 2 feet and 2 inches thick, separated by 60 feet of gray shale. Both limestones carry *Chonetes aurora* with several other fossil species. Beneath the lower are shales of Hamilton age, and above the upper is the Burket. Here, and here only, has a split or recurrence of the limestone been seen. Tully conditions of sedimentation and Tully fossils repeat, separated by a mud-forming interval. Tatesville is at the southern end of a narrow, elongated outlier of the Tully in eastern Bedford County. South of Everett, the Burket black shale rests directly upon the Hamilton with no vestige of intervening limestone. North of Tatesville, at locality 7 near Eichelbergertown, the Tully shows in a road cut. There are here 2½ feet of the rock between Burket and Hamilton shales. Probably the band of Tully extends no farther north, as it is not known at this longitude in Huntingdon County. This is the easternmost occurrence so far south.

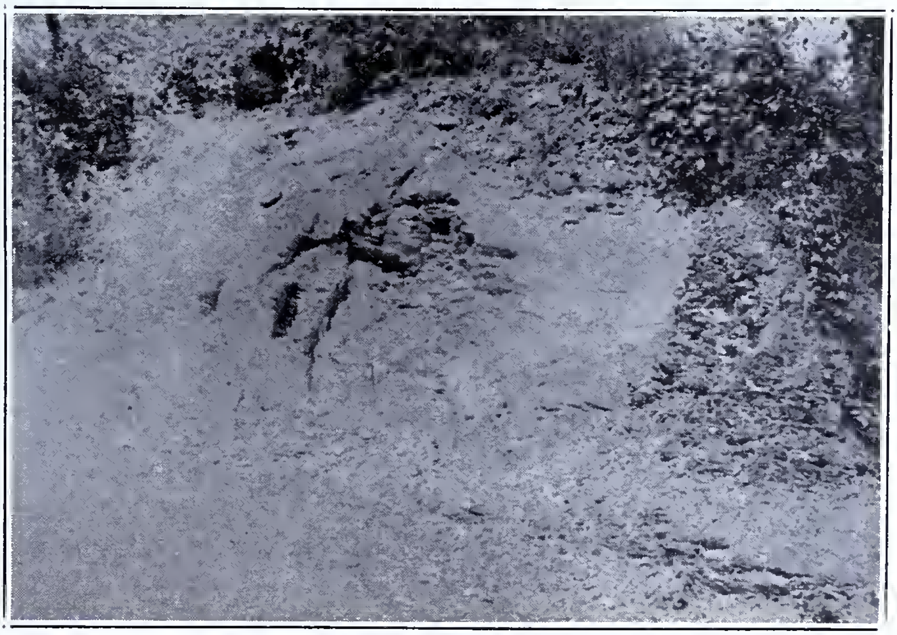
The Tully member does not occur much south of Schellsburg in Bedford County, but maintains a fairly uniform thickness north of that village. At Centennial School (locality 10) and in Dunning Creek Valley at locality 11, 3 feet show. Four feet of limestone and eight of underlying Tully shale above the Hamilton have been recognized at locality 12 at Imler. The member thins slightly north into Blair County to about 2 feet at Sproul (locality 13). Butts recorded a foot of limestone at the top of the Hamilton near Altoona (locality 15). Northward the thickness increases gradually to not less than 7 feet in highway cuts near Port Matilda (locality 16), and on the same road, U. S. Route 220, 2 miles east of Unionville at locality 17, there is 30 feet of Tully. There is 32 feet of limestone on Bald Eagle Creek near Curtin (locality 18) to which thickness may be added 3 or 4 feet of limy shale between the massive limestone and the Burket shale. This, incidentally, is one of the best exposures of the Tully in south-central Pennsylvania. Thirty feet seems a fair estimate of the thickness in a rather poor exposure in a highway cut near Blanchard (locality 19). At localities 16, 17, 18, and 19 along the north side of Bald Eagle Valley are exposures of Tully which for years was mistakenly mapped as Helderberg. That group, however, is confined to the southeast side of the valley and is separated from the Tully by probably not less than 1200 feet of Oriskany and Middle Devonian beds. The Tully in this region, particularly where deeply weathered, may be easily mistaken for the Onondaga unless due cognizance is taken of the diagnostic faunas.

Continuing north into Clinton and Lycoming counties, a remarkable thickening of the Tully is observed. From an estimated mere 30 feet at Blanchard, the aggregate of limestone and shale jumps to not less than 200 feet at Lockport across the Susquehanna River from Lock Haven (locality 20). As the horizontal distance involved is but 10 miles, the change is all the more surprising. This remarkable thickness continues eastward for 15 miles. A partial section in a quarry north of the railroad at Jersey Shore shows at least 75 feet of the limestone. Along State Highway 44 at the second bridge across the Susquehanna east from Jersey Shore about 100 feet of Tully shows in the river bank. The base and between one- and two-thirds of the lower portion of the member are hidden, and the whole is considerably faulted and twisted (locality 21, Figure 59).



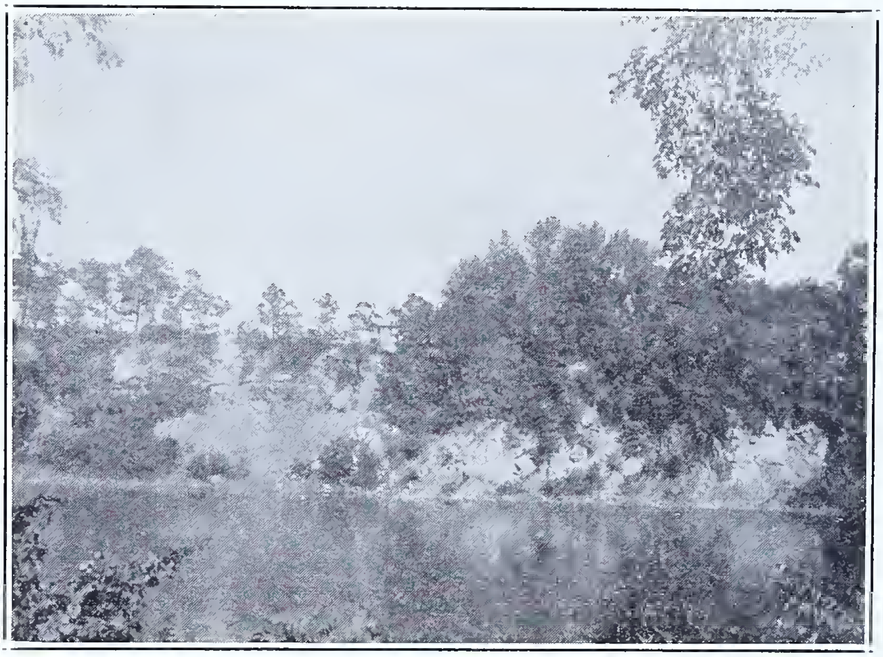
Photograph by Bradford Willard

Figure 57. **Ancient, long-abandoned kiln (note trees growing from top) in which Tully limestone was burned, near Schellsburg, Bedford County.**



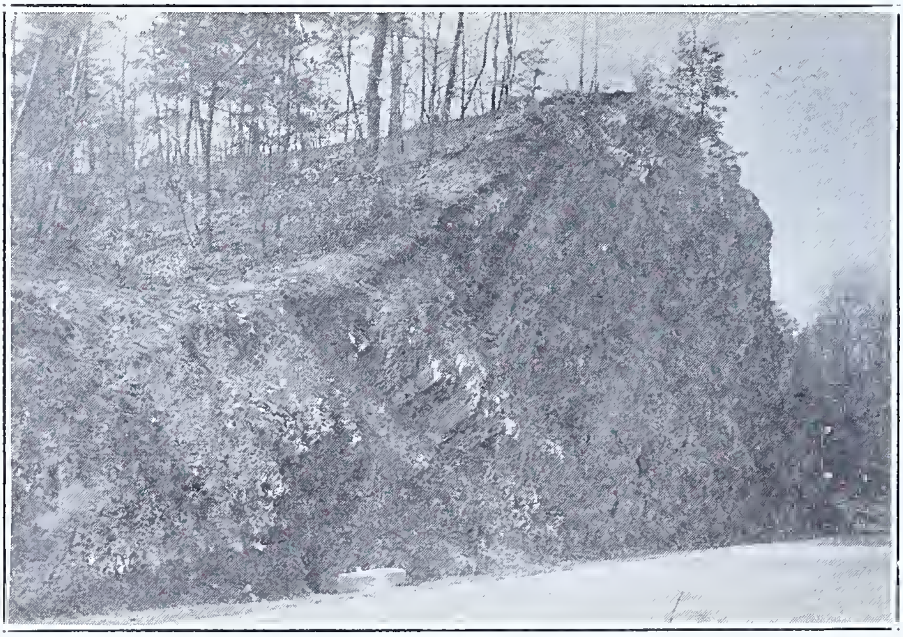
Photograph by Bradford Willard

Figure 58. **Shaly, uppermost Tully on Bald Eagle Creek near Curtin, Centre County.**



Photograph by Bradford Willard

Figure 59. **Tully exposed along the Susquehanna River at second highway bridge on State Route 44 east from Jersey Shore, Lycoming County. Burket black shale in the high bluff, left, the contorted limestone in center and right.**



Photograph by Bradford Willard

Figure 60. **Tully in cut at South Danville, Northumberland County. The limestone passes below ground at the small culvert. Above it (left) is Burket black shale. Under the limestone (right) is shaly Tully which rests upon uppermost Hamilton beds (right of center of picture). This is the locality at which the first authentic occurrence of Tully limestone and its fauna was determined in Pennsylvania.**

The greatest thickness was measured along the bank of the Susquehanna River and the tracks of the New York Central Railroad 2 to 3 miles east of Jersey Shore south of Larrys Creek Station. Two long, low anticlines bring the limestone to the surface. The maximum is 240 feet in the higher, southern anticline, but in both folds the base is concealed.

From Larrys Creek Station eastward the Tully thins rapidly. On Oak Run (locality 23) there are only 5 feet of limestone associated with perhaps 50 or 60 feet of limy shale above 11 feet of shale with limestone nodules which may be included with it. The lower shale rests upon rocks of Hamilton age. West of Hughesville (locality 24) a little residual, reddish clay probably marks the position of the Tully between the Hamilton and the Burket. At South Danville, Northumberland County (locality 25) there is an exposure of 10 feet of Tully limestone and 13 feet of overlying limy shale with Tully fossils. It is here that *Hypothryidina* was first discovered in Pennsylvania as I announced in 1934 and 1935. Doubtfully, I include in the Tully 20 to 25 feet of barren limy shale below the limestone. This is one of the easternmost known outcrops of the dominantly calcareous Tully in the State. Eastward from here along the Berwick anticline, occurrences of Tully fossils in limy shale are known from north of Bloomsburg on Highway 42 along Little Fishing Creek, on U. S. Highway 11 east of Beach Haven and one-half mile northwest of Eyers Grove southwest from Millville. A similar find was made on Fiddlers Run in southern Northumberland County at the juncture of U. S. Highway 15 and State Highway 225. A like exposure was found on U. S. Highway 15 north of Northumberland. In eastern Perry County along the Juniata River 8 miles below Newport (locality 26), about 2 feet of gray shale and hard limestone nodules carry *Hypothyridina venustula, Lopholasma tullium, Chonetes aurora* and other characteristic fossils. These beds rest on top of the Mahantango shale with *Vitulina* abundant, and are succeeded by the Burket shale. A similar occurrence is known on State Highway 5 between Duncannon and New Bloomfield, at Barnetts Mill, and at other scattered exposures north thereof in Perry County. On the Pennsylvania Railroad below Marysville about 50 feet of shale separating the Moscow from the Burket carry Tully fossils including *Lopholasma tallium, Elytha fimbratea , Echinocoelia, Atrypa spinosa* and *Lorhynchus, etc.* A similar fauna is known in Schuylkill County about 3½ miles north of Summit Station and on the Reading Railway north of Auburn. Both of these are without *Hypothyridina.* A well developed limestone with Tully fauna has been found on the east side of the Lehigh in cuts on U. S. Highway 309 north of Bowmanstown.

The Tully limestone has been recognized over a wide area in New York (80). In the region between exposures in New York and Pennsylvania where the beds pass under coal fields, subsurface data interpreted by Fettke (91), show that it is present from Elk County east to Bradford County. The maximum thickness he reports is 129 feet in Bradford County. This ties in with the great thicknesses in Clinton and Lycoming outcrops. Singularly, only a few miles south of

Jersey Shore in Union, Snyder and Mifflin counties, no Tully has been found. Instead, the Burket appears in disconformable contact with the uppermost Hamilton. The thicknesses of the Tully may be tabulated as follows:

Table XXIV, Tully thicknesses in Pennsylvania

In all sections where "plus" follows a given thickness, the implication is that one or both contacts is hidden.

Locality No.	Name	Shale below limestone Feet	Limestone Ft.	Limestone In.	Shale above limestone Feet
5	Tatesville		2	2*	
7	Eichelbergerstown		2	6	
9	Schellsburg		4		
10	Centennial School		3		
11	Dunning Creek		2 plus		
12	Imler	8 (?)	4		
13	Sproul		2 (?)		
15	Altoona		1		
16	Port Matilda		7		
17	Unionville		30 plus		
18	Curtin		32		3-4
19	Blanchard		30		?
20	Lockport		185 plus		12-20
21	Jersey Shore		90 plus		10
22	Larrys Creek		240 plus		10-15
23	Oak Run	11	5		50-60
25	South Danville	20-25	10		13
26	Perry County		4 (shale with limestone nodules)		
27	Schuylkill County		2 (limy shale)		
28	Brodhead Creek		73 (Laurens sandstone)		

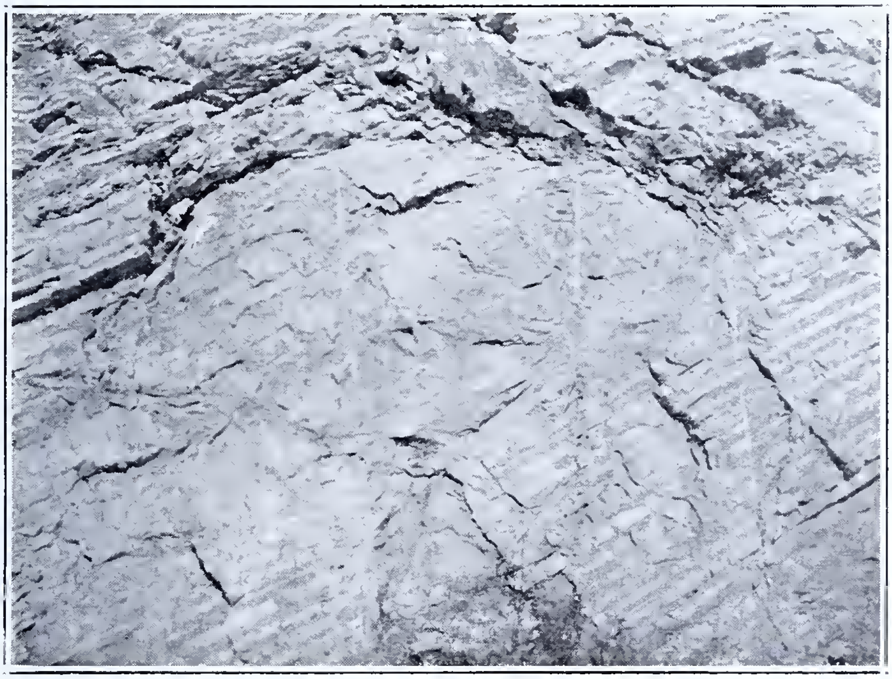
* In this section there are two limestones, the lower two inches thick, the upper two feet thick, separated by about sixty feet of dark shale. Both limestones carry Tully fossils. This interrupted succession is unique in Pennsylvania so far as known.

In addition to the above thicknesses, the following may be noted. Most of them are for sections composed of shale or very shaly limestone in which Tully elements occur, usually without *Hypothyridina*. They are not indicated by numbers on the map, Figure 54.

	Feet
North of Northumberland	10 plus
Southwest of Millville	2 plus
Little Fishing Creek	30
East of Beach Haven	20
Fiddlers Run	2
South of Marysville	50
North of Summit Station..................	10
Auburn	?
North of Bowmanstown..................	20±

Although the Tully limestone in Pennsylvania does not appear as readily divisible into successively younger units as in New York, it does permit of differentiation into two distinct *phases* or *facies*. These occupy relatively northern and southern areas and may be referred to respectively as the platy and massive types.

The platy facies occurs in the thicker, northern sections such as that on Larrys Creek (locality 22), and those near Jersey Shore (locality 21) and at Lockport (locality 20). In some of the thinner sections, at South Danville (locality 25) and in part at Curtin (locality 18), this phase is also recognized. The platy Tully is characteristically light-gray, non-crystalline limestone whose bedding averages about 2 inches thick (fig. 61). Usually, the limestone beds are separated by thin black shale partings. In only a very few sections is the base exposed, but apparently it usually passes over into limy shale which rests in disconformity upon Middle Devonian beds. Upward, a change may be observed in the top of the sections where the limestone grades into the Burket black shale. The platy limestone weathers brownish to light-gray, and is usually fetid if a fresh specimen be hammered. Except in the highest beds of the limestone and the shaly top of this member, fossils are quite rare. The Tully east of the Susquehanna Valley is in general shale or at best limy shale. In Northumberland, Columbia and Luzerne counties it is fairly calcareous, but highly sheared. Lime nodules occur in the shale in the Juniata Valley outcrops in Perry County, but south of Marysville only shale was observed, though it is probable that, were it less highly weathered, it would show limy beds. The Schuylkill County occurrences are both quite shaly. These shaly outcrops are all characterized by the general absence, save in eastern Perry County, of *Hypothyridina*. With the recurrence of limestone in the Lehigh Valley, this fossil is again encountered, and it is known on



Photograph by Bradford Willard

Figure 61. **Detail of platy Tully limestone, Lockport, opposite Lock Haven, Clinton County.**

Brodhead Creek in the sandy "Laurens." It also appears, but very sparingly, in the limestone at South Danville, Northumberland County.

The massive development of the Tully carries a larger fauna than does the platy phase. The faunas of the two phases are distinctive. Corals, including *Lopholasma*, are found chiefly in the platy type in the north, rarely in the massive southern Tully. *Elytha fimbriata* and most of the "*Spirifer*" species, the mollusks and some of the trilobites are representative of the platy phase. In its higher beds *Atrypa spinosa* and *Phacops rana* may be common. The massive beds, conversely, carry a large, newly described species of brachiopod, *Emanuella pennsylvanica*, with hordes of *Chonetes aurora*. The last named fossil is rare in the platy phase of the northern sections. It is occasionally associated with *Echinocoelia ambocoelioides* and *Hypothyridina venustula* in the platy limestone. The faunas of these two phrases are presented in Table XXV on pages 232-233:

There is no sharp separation between these distinctive phases of the Tully either geographically or stratigraphically. Where they occur alone, they are clearly distinct, but where found in the same section, their close relationship is at once clear. Otherwise, it might appear that they were non-contemporaneous, and direct correlation with the subdivisions of the New York Tully as established by Cooper and Williams might be feasible. At Curtin (locality 18) the relationship between platy and massive limestones is well illustrated. Platy limestone identical in lithology to that at Lockport, Larrys Creek, etc., carries interbedded strata of massive limestone up to a foot thick which is lithologically the counterpart of the southern phase. At Curtin as at Lockport, the shaly beds at the top intergrade with the succeeding Burket, and in these upper beds is a zone in which *Atrypa spinosa* and *Phacops rana* abound. Assuming, on reasonable grounds, that the tops of these sections are essentially contemporaneous, it is quite evident that the massive limestone of the south equals the upper portion only of the platy northern sections. Conversely, in the thick northern sections, the lower part may be older than the southern Tully, unless quite unequal rates of sedimentation are postulated. In support of this lithologic transition at Curtin, note that *Emanuella pennsylvanica* was found here in association with *Echinocoelia ambocoelioides* and a single fragment of *Hyprothyridina*, but no *Chonetes aurora*. The generally shaly eastern beds are presumed to be partly contemporaneous to the limestones but representing and muddy, near-shore phase of environment.

The *correlation* of the Tully is an item of significance. I observed that, because of the apparent contemporaniety of the two phases, the member does not admit of such subdividing as has been accomplished in New York. Nevertheless, I offer comparisons with the findings of Cooper and Williams (80) who described the following divisions in New York.

Tinkers Falls member [lower]

The type section of this member is in the face of Tinkers Falls just under the main, overhanging ledge. Here it is represented by 6½ feet of alternating thin layers of dark calcareous shale and shaly limestone,

Table XXV, Tully faunas in Pennsylvania

Fossil	Schellsburg	Centennial School	Dunning Creek	Imler, shale	Imler, limestone	Eichelbergerstown	Tatesville, ls. on rd	Tatesville, sh. on rd.	Tatesville, R. R. 180′	Tatesville, R. R. 240′	Sproul	Unionville	Curtin	Locknort	Shore	Larrys Creek	S. Danville shale	S. Danville limestone	Brodheads Creek	Perry County
Enterolasma rectum (Hall)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	x	--	--
E. sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--
Zaphrentis sp.	--	--	--	--	--	--	x	--	--	--	--	--	--	--	--	--	--	--	--	--
Amplexus hamiltoniae Hall	--	--	--	--	--	--	--	--	--	--	--	--	x	x	x	x	x	x	--	--
Lopholasma tullium J. S. Williams	--	--	--	--	--	--	x	--	--	--	--	--	x	x	x	x	--	?	--	x
L. sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--
Aulacophyllum sulcatum d'Orbigny	--	--	--	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aulopora sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--
Ceratopora dichotoma Grabau	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--
C. sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--
Favosites sp.	--	--	--	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pleurodictyum sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--
Corals, undet.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	x	--	--
Taonurus sp.	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--	--
Crinoidea, columnals	x	--	x	x	x	x	x	--	x	--	x	x	x	x	x	x	x	x	x	x
Fenestella sp.	--	--	--	--	--	--	--	--	x	--	--	x	--	x	x	--	--	--	x	--
Strictopora sp.	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--	--	--	--
Bryozoa, undet.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	x	x
Lingula ligea Hall	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--
Pholidops sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--
Stropheodonta demissa (Conrad)	--	--	--	--	--	--	--	--	x	--	--	--	x	--	--	--	--	--	--	--
S. sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--
Leptostrophia perplana (Conrad)	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--
L. sp.	--	--	--	--	--	--	--	--	--	x	--	x	--	x	--	x	--	x	--	x
Douvillina sp.	--	--	--	--	--	--	--	--	--	--	x	--	--	x	--	--	--	--	--	--
Leptaena rhomboidalis (Wilckens)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--
Schuchertella variabilis Prosser	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--
Chonetes aurora (Hall)	x	x	--	x	x	--	--	x	x	x	x	x	--	--	--	x	--	--	--	x
C. lepidus Hall	--	--	--	--	--	--	--	x	--	--	x	--	--	--	--	--	--	--	--	--
C. coronatus (Conrad)	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--	--	--	--
Productella spinulicosta Hall	--	--	--	--	--	--	--	--	--	--	--	--	x	--	x	x	--	--	--	--
Dalmanella sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--
Rhipidomella vanuxemi (Hall)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--
R. sp.	x	--	--	--	--	--	--	x	--	--	--	--	--	--	--	--	--	--	--	--
Camarotoechia orbicularis (Hall)	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	x	--
C. eximia (Hall)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--
Liorhynchus mesacostale (Hall)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--
L. globuliforme (Vanuxem)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--
L. sp. (cf. *limitare*)	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--	--	--	--	--	--
L. sp.	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hypothyridina venustula (Hall)	x	x	x	--	--	x	--	--	--	--	x	--	x	--	--	--	--	x	x	--
Pentamerella sp.	--	--	--	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tropidoleptus carinatus (Conrad)		--	--	--	--	--	--	--	x	--	--	--	--	--	--	x	x			?
Atrypa spinosa Hall		--	--	--	--	--	--	--	--	x	--	--	x	x	x	x	--			x
"*Spirifer*" *mesastrialis* Hall		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x		--	--
"*S.*" *mucronatus* (Conrad)	-	--	--	--	--	--	--	x	--	--	x	--	--	--	--	--	--		--	--
"*S.*" *m.* var. *posterus* Hall and Clarke	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	x	--

Table XXV, Tully faunas in Pennsylvania—Continued

Fossil	Schellsburg	Centennial School	Dunning Creek	Imler, shale	Imler, limestone	Eichelbergerstown	Tatesville, ls. on rd.	Tatesville, sh. on rd.	Tatesville, R. R. 180′	Tatesville, R. R. 240′	Sproul	Unionville	Curtin	Lockport	Jersey Shore	Larrys Creek	S. Danville shale	S. Danville limestone	Brodheads Creek	Perry County
"S." tullius Hall									x		x		x	x		x				
"S." pauliformis J. S. Williams																		x		
"S." sp.														x					x	x
Elytha fimbriata (Conrad)													x		x	x		x		x
Ambocoelia umbonata (Conrad)													x			x		x		
Echinocoelia ambocoelioides Cooper and Williams	x	x	x	x	x	x		x		x	x	x	x	x		x	x	x	x	x
Cyrtina sp.				x											x			x		
Charionella ovata (?) J. S. Williams											x		x							
Emanuella pennsylvanica Willard						x				x			x							x
Coelopsira ?													x							
"Martinia" sp.	x	x	x	x						x	x		x							x
Athyris sp.																			x	
Grammysia arcuata (Conrad)								x												
Buchiola susquehannica Willard																x				
Nucula corbuliformis Hall																	x			
Palaeoneilo sp.														x						
Leptodesma sp.													x							
Actinopteria boydi (Conrad)														x						
Cypricardella sp.																x				
Paracyclas sp.																	x			
Pleurotomaria capillaria Conrad											x									
P. sp.														x		x	x			
Euomphalus sp.													x							
Loxonema hamiltoniae Hall													x							
Platyceras carinatum Hall															x					
Styliolina fissurella (Hall)								x				x		x		x		x		
Tentaculites descissus Clarke and Swartz	x																			
T. bellulus (Hall)																	x			
Hyolithes sp.																x				
"Orthoceras" sp.													x							
Spyroceras nuntium (Hall)													x					x		
Baeopleuroceras incipiens J. S. Williams													x							
Probeloceras lutheri Clarke																x				
Bactrites sp.									x											
Phacops rana (Green)												x	x	x	x	x				x
P. sp.							x									x	x		x	
Proetus rowi Green														x						
Greenops (Dalmanites) boothi (Green)																x		x		
G. b. var. *calliteles* (Hall and Clarke)													x		x	x				x
G. bedfordensis Willard	x				x															
G. sp.														x		x				
Ostracoda, undet.												x				x				
"Ostracoderm" plate, undet.															x					
Plant fragments, woody													x						x	
Fucoids													x				x			

abounding in *Chonetes aurora*. This species occurs in swarms on the surface of the rock, and scarcely any other species are present. At June's Quarry and ravine not far west of Tinkers Falls this member is only 1½ feet thick, but east of the type section it thickens to about 14 feet at the north end of Deruyter Reservoir, Cazenovia Quadrangle.

Apulia member [middle]

The type section of the Apulia member is in the ravine adjacent to June's Quarry, 1½ miles southwest of Apulia Station, Tully Township. It is a hard, heavy-bedded, arenaceous limestone containing *Hypothyridina* in great numbers and at several levels. Members of this genus are most abundant in the lower beds. Other fossils characteristic of this zone in the vicinity of the type section are *Schizophoria tulliensis*, *Chonetes aurora*, and *Leptostrophia tulliensis*. These three species become rare west of the type section.

West Brook member [upper]

Following the Apulia member are 10 feet of dark gray, shaly limestone. In the lower half of this member occur many species of fossils, chiefly Hamilton species, the most abundant of which is *Elytha fimbriata*. The upper half is characterized by the coral *Lopholasma*. Although this upper member of the Tully is well developed at June's ravine, it is more fossiliferous farther east in Chenango Valley. The locality selected as the type section, therefore, is on West Brook, 3 miles south of Sherburne.

The platy phase in Pennsylvania resembles faunally and lithologically the West Brook member of the upper Tully in New York, but it also has certain similarities to the Tinkers Falls or lower New York Tully. Nevertheless, *Hypothyridina* is present, but is unknown in the Tinkers Falls, while *Echinocoelia*, an Apulia fossil, occurs, though not commonly, in several sections of the platy phase. The massive or southern type of Tully in Pennsylvania contains *Hypothyridina* commonly and great quantities of *Chonetes aurora*. The only *Charionella* was found in the massive Tully, but this genus is known in New York only in the West Brook member. I am inclined to look upon these confusing data for the Pennsylvania Tully as indicating that it is nearest the equivalent of the upper part of the New York Tully. The lithology and fossils are a combination of those found in separate members in New York. Though they may not always be found together in a single locality in Pennsylvania, at least they may be shown to be nearly contemporaneous with lateral intergradation.*

A passing remark regarding the Tully fossils at locality 28, Brodhead Creek, Monroe County, is in order. They have already been mentioned in discussing the Middle-Upper Devonian contact and the Trimmers Rock member. It will be recalled that at that locality in the base of the Trimmers Rock, there was found a faunule of considerable significance because it combines Ithaca and Tully elements. I have suggested that it is the lithologic, stratigraphic and faunal equal of the Laurens member of New York. The association of *Liorhynchus mesacostale*, *Hypothyridina venustula* and *Echinocoelia ambocoelioides* is suggestive of the Laurens.

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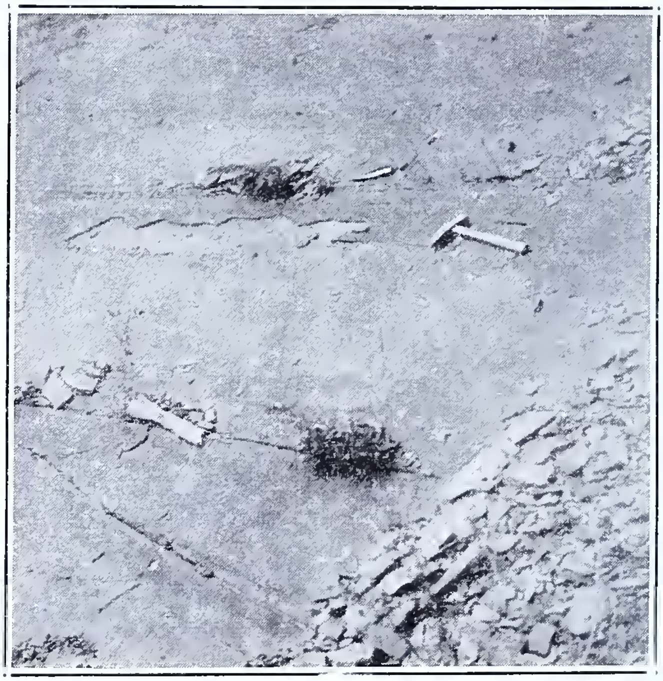
* In September 1937 and July and September 1938, Dr. Cooper and I visited most of the Tully localities in Pennsylvania. Many of them suggested the West Brook to him, but in Perry County he noted resemblances to the Apulia. The *Hypothyridina*-poor, eastern shaly beds may be of West Brook affinities.

Portage Climate

Evidence touching upon ancient climatic conditions is usually interesting, and in the case of the Portage some information has been obtained that is rather exceptional and apparently is unique for the Paleozoic of Pennsylvania. In New York, evidence has been cited for the presence of ice during Devonian time. Striated sandstones were observed long ago by James Hall (111) and later described by John M. Clarke (67, 68) in his discussion of the Portage of that State. His interpretation was that they were produced by tide-driven ice, scraping bottom. No contemporaneous glaciated pebbles or morainal material were recorded in New York, but what are interpreted at fluvio-glacial gravels are known from rocks of this age in the Province of Quebec. Devonian glaciation probably occurred in southeastern Alaska, according to Kirk's interpretation (129).

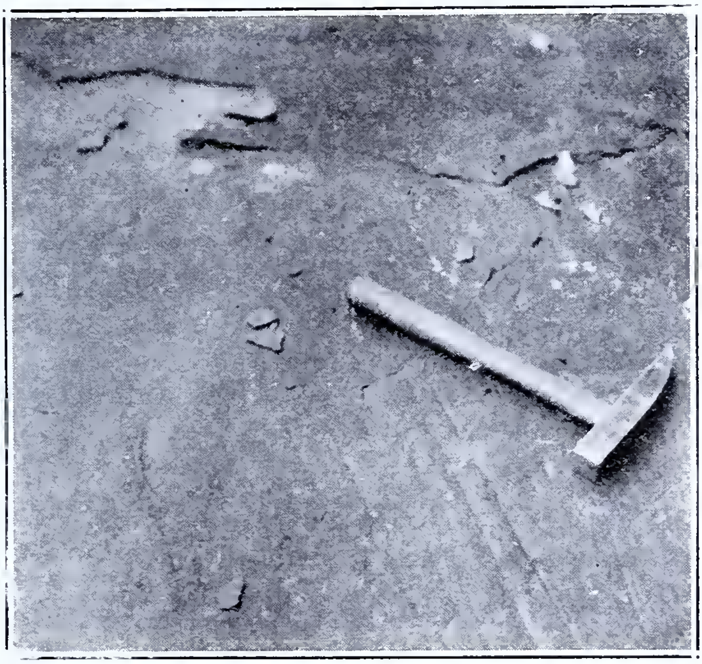


Photograph by Bradford Willard

Figure 62. **Striated Portage sandstone near Blairs Mills, Huntingdon County.**

Schuchert (184) has supplemented Clarke's observation with a faunal analysis of the fossils contemporaneous with the supposed ice in New York and has shown that the disappearance of corals, reduction in number of species and the geographic relations of the cephalopods and pteropods indicate a cooler climate in late than in middle Devonian time. My observations on the faunas are similar, although corals did continue sparingly into post-Portage time in Pennsylvania. Fossil plants of contemporaneous age are useless in this instance so far as known.

In the Portage of Pennsylvania striations believed to be ice-formed have been observed (243). In east-central Huntingdon County a section along the Trough Creek Branch of Tuscarora Creek and State Highway 829 parallel thereto between Blairs Mills and Shade Valley post office (Richdale) is exposed across a broad, shallow, symmetrical syncline of Devonian formations, ranging from the Helderberg into the Catskill, here mostly of Chemung age; for the red beds grade down into the top of the Portage with no marine Chemung recognized. The Trimmers Rock sandstone with an Ithaca fauna forms the higher Portage beds, and this rests upon well-developed greenish Brallier shale with the characteristic fossil trail *Pteridichnites biseriatus* associated with carbonized plant shreds, mud chips and doubtful *Fucoides graphica.* Below the highest Brallier is a concealed interval of 20 feet. Then follows a sequence of nearly 100 feet of rather sandly Brallier. It is in these beds that the striated surface was observed. It is about 225 feet above the dark shales of the lower Portage. No fossils were found in the striated portion, but in adjacent beds is a spare Naples fauna of small pelecypods, pteropods and goniatites. The striations are on a smooth bedding surface about 30 feet square exposed by road construction. The surface strikes N. 37° E. with a dip of 26° S. The scratches trend N. 73° W. The largest striations are grooves 30 mm. wide and 12 mm. deep, but there are many smaller ones so that the average width and depth are 10 and 5 mm. respectively. (Figures 62 and 63.) A gradual change in size along an individual scratch may be observed. Mutually parallel, the scratches suggest a single movement of the body



Photograph by Bradford Willard

***Figure 63.* Detail of striated Portage sandstone shown in Figure 62, near Blairs Mills, Huntingdon County.**

which produced them. They are very similar to those caused by Pleistocene glaciation; but, not only are they at least 35 miles south of the nearest known moraine (139), but also they are inter-bedded in the Portage, passing out of sight between undisturbed, consolidated rock.

There is thus no question as to the late Devonian age of the striae. Human agents may be eliminated, for there are neither pick nor power-shovel marks on the surface, and the grooves are 20 to 30 feet long. The suggestion of their having been produced by iron wagon tires is untenable because they disappear between strata. No carbon or other organic material was found in the scratches, nor is there evidence of segmentation such as might be expected were they stem imprints; neither are they branched. Plant imprints and rill marks are thus ruled out of possibilities. Slickensides, they are not. Although parallel with one another, they are not perpendicular to the axis of the syncline. The dragging of roots or other objects across the unconsolidated sediments offers an inadequate explanation for these symmetrical lines. Apparently, ice and ice only is the explanation, a supposition substantiated by the recognition of faint chatter-marks.

We might accept, with modifications or reservations, Clarke's theory of shore-ice. By this theory, blocks of ice are supposed to be moved by tide or current up and down the strand line either above or below high-water mark. Widening of respective grooves is attributed, not to wearing down of points, since the beach sediments would be unconsolidated and incapable of so doing, but deeper digging of the abrading points as the mass moved up the beach. Clarke held that, as the marks he noted were found only in sandstone and not shale, the material must have been soft; and, therefore, the impression was not retained by the mud. Such a suggestion seems borne out by lack of sharpness of newly exposed striae, but the occurrence of chatter-marks is at variance with such a suggestion. For these reasons we are inclined to believe that originally the bed was partly consolidated and so retained the impressions fairly well until buried, preserved and indurated into still more solid rock. That the sediments may not have been fully consolidated when being scratched is inferred from lack of evidence of a pronounced disconformity at the bedding surface upon which they occur.

Because the scratches are simple, a single movement is deduced. The marks should have been made by a continuous push, not the shuttle movement of tide-borne ice. There is no compound pattern, only a simple series of parallel lines. Perhaps, instead, the ice was current borne or washed ashore in a single movement, and as it did so, left striae upon the stiff, clayey sand of the ocean bed. Professor R. T. Chamberlin suggests (personal communication) that they may be due to ice-rampart shoving such as might be postulated for a lagoon. This comes closer to actual glacial action than the theory of origin through water-borne ice. Evidently the exact method by which these peculiar markings were made is still uncertain, but it is reasonably sure that ice caused the striae. Also it was moved in a near-shore region and on beds that now lie but a short distance below continental red strata. The adjacent shore-line was not fixed but was then building rapidly northwestward. The faunal evidence points to a cool, but not necessarily a severe climate. The abundance of what is supposed to be shredded, carbonized, terrestrial vegetation is significant. Perhaps the ice may be interpreted best as merely an expression of cold winters; certainly it does not imply a glacial interval with continental ice sheets. There is no recorded sign of wide-spread or severe ice action in eastern North America at that time.

Origin of the Portage Group

The Portage group of Pennsylvania embraces the median part of a marine regression of a great Devonian cycle of sedimentation. Our Middle Devonian formations illustrates at least the earlier portion of the recession, and the interval of stillstand. In the still higher marine units and the continental Catskill are read the closing events of this same cycle. Thus, the earlier Devonian represents marine on-lap, the earlier Portage formation (the Rush) is indicative of approximate standstill during an interval of temporary interruption. The younger Portage (Fort Littleton formation) and the later Upper Devonian record progressive marine off-lap terminating in the Catskill sub-aerial facies. This is first recorded for eastern Pennsylvania in middle to later Portage time. In discussing the Catskill it will be shown that this continental off-lap began even earlier, in early Hamilton time, perhaps late Marcellus, in north central New Jersey. First, a brief consideration of the origin of the Tully should precede the discussion of the Portage as a whole according to the above concept.

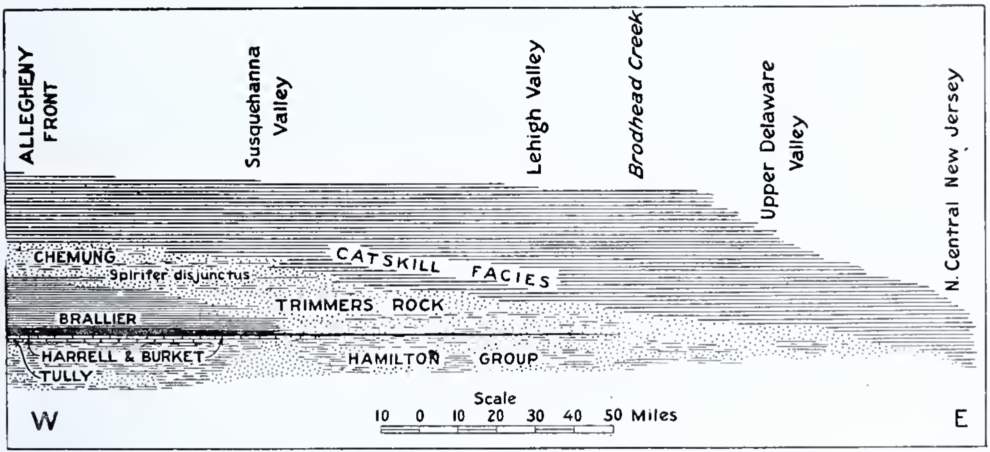


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Figure 64. Schematic east-west section to show relations of Portage group to the underlying Hamilton group overlying Chemung group, and the Catskill continental facies. Vertical scale greatly exaggerated.

The rapid changes in thickness, the lithologic differences, the diminution of limestone in the Tully east and southeast of its chief line of outcrop in Pennsylvania, suggest unusual conditions perhaps associated with an indented coast with protected lagoons and barrier reefs. This theory, however, is not supported by an abundance of corals or reef-building organisms in the Tully. The Tully-Hamilton disconformity is significant. Nowhere has a transition been observed at this point. In most central and eastern Pennsylvania sections a *Vitulina* zone marks the highest Hamilton faunule. In south-central parts, where this fossil is unknown, the highest Hamilton beds may be presumed to be lacking, although no evidence of an unconformity has been noted. All contacts there are merely disconformable. This break appears to be non-depositional, rather than diastrophic. The basal Burket is supposed, from its relations and fauna, to be essentially synchronous across Pennsylvania. The Tully limestone itself dies out southward so that the Burket rests upon the Hamilton. The Harrell overlies the Hamilton in southern Bedford County, and in Fulton County the Hamilton is capped by beds assigned on lithology to the lower Brallier. This implies on-lap toward the south or southeast from Tully to early Brallier time. The assumption is, that, following local off-lap in late Hamilton (probably Moscow) time, there was an interval of non-deposition whose duration increased southeastward. The Tully sea then overspread much of central and eastern Pennsylvania. Off-shore reefs have not been discovered as yet, but may have developed. With slow transgression, the lower portions of the thicker sections to the north in Clinton and Lycoming counties, and, judging from well records, beyond in Bradford County, probably began to form before the sea spread to the region where the more southern extension of the limestone occurs. If so, only the highest beds in the thick sections may equal the entire Tully in the thinner sections to the south where the Middle-Upper Devonian diastem is greatest. I have postulated that south-central Pennsylvania during much of the Paleozoic was unstable. Such an hypothesis may be substantiated by this break. Apparently the Tully limestone never encroached far east of the Susquehanna Valley because between Perry, Luzerne and Northumberland counties the beds are clastic, reaching an extreme in the sandy "Laurens" of Monroe County.

Turning from the Tully specifically to the Portage, generally in eastern Pennsylvania the Trimmers Rock sandstone and the sandy facies of the Middle Devonian converge stratigraphically and faunally. It is conceivable that they actually approach and become intertransitional. This is a counterpart of conditions reported by Cooper in eastern New York where he finds the Laurens with Tully elements in its fauna, and Portage with a "modified Ithaca" fauna mixed with Hamilton elements. I have noted and will describe fully below, that in north-central New Jersey the Catskill continental red beds cut far down into the Middle Devonian, perhaps as low as the top of the Marcellus. These oldest red beds then represent the earliest record south of the Hudson River Valley (where a like condition is known) of continental conditions in our Devonian sequence. They imply uplift of the adjacent region to the southeast or east. Such an uplift presumably accentuated Portage deposition following the earlier reversal of the circle. The off-lap continued through and beyond Portage and Chemung times, the red beds building west or northwest across Pennsylvania, their base rising steadily with progressive continental off-lap. Of this outbuilding and the probable nature of the coast, more will be said in describing events of Chemung and later times.

The Devonian outcrops of the upper Delaware Valley and of north-central New Jersey are separated by an area in which Devonian rocks are lacking. In that region one would logically expect to find the traces of the reversal of movement of the sedimentary cycle, from positive eastward on-lap to negative, westward off-lap. On Brodhead Creek, Monroe County, the Portage can be separated from the Hamilton by faunal data; northeast of that point no such criteria generally avail. Tully, Burket and Moscow elements are unknown. The Trimmers Rock sandstone of the upper Delaware Valley above Port Jervis carries "*Spirifer*" *mesastrialis*, *Palaeoneilo emarginata*, *Actinopteria boydi* and *Paracyclas lirata*. The first three are absent from the Hamilton sandstone of the river bluffs at Port Jervis and Matamoras, beds well dated from their occurrence not far above the locally thick Marcellus. The strata immediately between those which are evidently Portage and those which are near the upper limits of the Hamilton, carry both *Palaeoneilo emarginata* and *Actinopteria boydi*. *Paracyclas lirata* may be present here also, but "*Spirifer*" *mesastrialis* is doubtfully identified. This evidence is interpreted to mean that here is truly a transition between beds of late Hamilton age and those representing the lower part of the Portage group. West from Monroe County, a wedge of marine shales divides the Trimmers Rock from the beds with Hamilton fossils. The Hamilton-Trimmers Rock transition therefore may record the progressive off-lap of the sandy or neritic zone facies in a region sufficiently near the coast to be unaffected by the temporary interruption of Tully-Burket time farther west.

The Rush formation and the overlying Fort Littleton formation exemplify, renewed and accelerated marine off-lap. When the Burket formed, the sea seems to have been almost devoid of life, but by Harrell time there was a marked influx of Naples forms which reached their best development in Pennsylvania during the laying down of this gray shale. Besides the Burket-Harrell faunal discrepancy, there is a fairly sharp lithic separation amounting locally to a disconformity. Throughout the Susquehanna Valley, but not known east of it, and continuing westward to the Allegheny Front, the Harrell is succeeded by the Brallier greenish shale. With its appearance, the Naples fauna is greatly reduced, and stray Ithaca forms appear. This influx of Brallier mud may have accompanied severer climatic conditions, the two combining to affect adversely the population off-shore. But, the Brallier is overlapped from the east and southeast and finally displaced by its coarser, clastic complement, the Trimmers Rock sandstone. As the one thickens, the other thins. The sandstone brought in an abundant, neritic or even littoral facies, entirely displacing the already decadent Naples life.

Eventually, at the close of Portage time, came the invasion of the Chemung or, more truly, the Portage fauna acquires a Chemung aspect with the appearance of "*Spirifer*" *disjunctus*. Neither lithic nor stratigraphic sequence is broken where only arenaceous facies are envolved. The final event is the eclipse of all marine sedimentation with the advent of Catskill continental beds. The cycle ended with the culminating deposition of fresh-water red and green beds bearing fragments of land plants and the remains of fresh-water (?) fishes.

Correlation

While not necessarily final, the following correlations are believed reasonably correct. Further data, especially such as may be obtained from subsurface correlations, may refine some of these suggestions.

The Maryland Geological Survey (143) divided the Upper Devonian into:

JENNINGS FORMATION
- Chemung member (*Spirifer disjunctus* fauna)
- Parkhead sandstone member
- Woodmont shale member
  - Beds containing Ithaca fauna
  - *Reticularia laevis* zone
  - Beds containing Naples fauna
- Genesee black shale member

From their lithic characters and faunas, direct correlation could be made with central Pennsylvania, even without the ability to trace the formations directly through from one State to the other. The Maryland Survey does not use the term Portage to any extent, preferring to group beds of that age with the Chemung under the heading Jennings Formation. This is not advisable in Pennsylvania because of the much better development of the later marine Devonian. The upper limit of the Portage group in both Pennsylvania and Maryland is drawn at the appearance of "*Spirifer*" *disjunctus*. In both States, the base comes at the top of the Hamilton.

The Parkhead of Maryland is recognized as extending into south-central Pennsylvania, and direct correlation is possible, although eastward, its separation from our Trimmers Rock is unknown beyond the Susquehanna Valley. It may be treated there as equal to the top beds of the Trimmers Rock sandstone until obliterated by continental strata. As the Parkhead tops the Portage in both Maryland and Pennsylvania, so the base of the group is marked by an equivalent dark shale, the Genesee of Maryland, the Harrel and Burket of Pennsylvania. Each may rest upon beds carrying a Hamilton fauna, except that the Tully, unknown in Maryland, wedges in beneath the black shale northward in Pennsylvania. The Maryland Survey denominates in the "beds containing Naples fauna" an equivalent of our Harrell gray shale. Their *Reticularia laevis* zone can hardly be anything else but our *Recticularia laevis* zone or the Losh Run shale. The Woodmont shale member above the *Reticularia* zone in the south clearly equals our Brallier, and, from the fact that it does carry Ithaca fossils and is partially composed of sandstone, it may be thought of as also including part of the Trimmers Rock sandy facies of our upper Portage.

An attempt to correlate the Portage of Pennsylvania with that of New York is more difficult than with Maryland, for direct tracing cannot be accomplished. The equivalent of our Portage (104) sequence, the Senecan, as given for central New York by Goldring is:

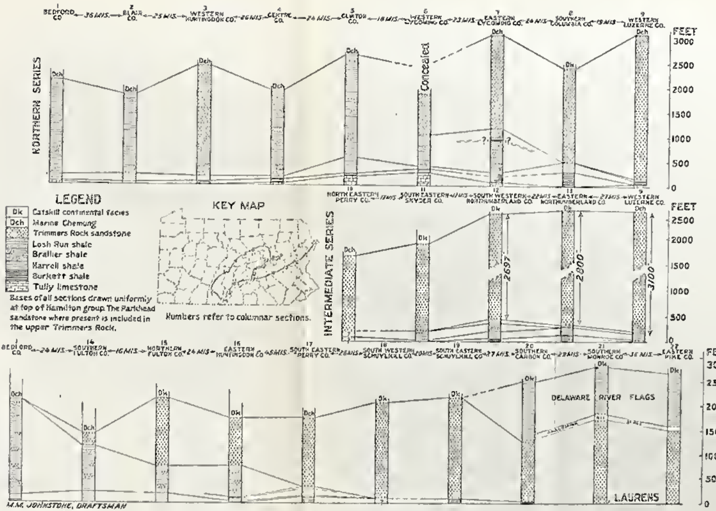


Figure 65. Correlation chart of Portage group in Pennsylvania.

SENECAN
Portage beds
(Naples-Ithaca fauna)
Enfield shale
Ithaca shale
Cashaqua shale
(Sherburne sandstone)
Genesee black shale
Tully limestone

As in Pennsylvania, the top of the group is drawn at the base of the Chemung, punctuated by the lowest occurrence of *"Spirifer" disjunctus*. The base is drawn at the Tully-Hamilton contact which may be fully as sharp in New York as in Pennsylvania. We observed that our Burket may equal what has lately been called Geneseo in New York, that is, the basal black shale member of Chadwick's Genesee group. The Cashaqua shale would seem from its Naples fauna to be the logical correlate of our Harrell, but, from its higher stratigraphic position, is probably a recurrent. The Trimmers Rock sandstone and its complementary correlate, the Brallier shale as a whole, may be assigned to a position equivalent to the Enfield and Ithaca shales and the Sherburne sandstone. There seems no very clear, direct correlation of these several units. There is, nevertheless, a prominent "*Reticularis laevis* zone" low down in the Sherburne which may be the equal of our Losh Run shale with its similar fauna. Assuming this as true, I suggest that the Trimmers Rock of eastern Pennsylvania may be substantially equal to the Enfield, Ithaca and Sherburne of central New York, while the Brallier shale is the undifferentiated equal of the several shalier members recognized as constituting the Senecan above the Genesee group farther west. Unfortunately, in Pennsylvania the Portage passes irrevocably beneath the Allegheny Front long before it can be broken up or clear differentiation is possible into those divisions recognized in western New York.

TABLE XXVI, THE PORTAGE OF THREE STATES
(See also Figure 65)

Maryland	Pennsylvania	New York
Chemung (*"Spirifer" disjunctus*)	Chemung (*"Spirifer" disjunctus*)	Chemung (*"Spirifer" disjunctus*)
Parkhead sandstone member	Parkhead sandstone	Enfield shale
Woodmont shale member	Brallier-Trimmers	Ithaca shale
Beds with Ithaca fauna	Rock shale and sandstone	Cashaqua shale
Reticularia laevis zone	Losh Run shale	Sherburne sandstone
Beds with Naples fauna	Harrell gray shale	Genesee group
Genesee black shale member	Burket black shale	Geneseo black shale
	Tully limestone	Tully limestone

It should be observed that recent revision of the Upper Devonian in New York makes speculation on exact and final correlation hazardous at present. Until the newly proposed interpretations have stood the test of exhaustive field application, these correlations are merely suggested possibilities.

CHAPTER VII.

UPPER DEVONIAN, Continued, CHAUTAUQUAN STAGE

Chemung, Canadaway, Conneaut and Conewango Groups

In this discussion of the Devonian of Pennsylvania, the highest marine groups which together comprise the Chautauquan stage have now been reached. No part of the system has elicited greater controversy. Most of the groups now to be described are well developed in northwestern Pennsylvania, but supplementary observations in southwestern New York are essential for completeness. From this region east of Lake Erie, a stratigraphically extremely intricate succession of varying marine sediments passes eastward into the non-marine facies equivalent. The region has been studied for many years by a number of independent workers, no two of whom are in full agreement as to the interpretation of the sequence. Each of the Second Pennsylvania Survey geologists assigned to northwestern Pennsylvania made and published a classification differing from those of all his fellow workers. These men were without any precedent, for Henry D. Rogers's 1858 map was totally detailless, and the accompanying text was inadequate (177). As usual with the Second Survey, there was a distressing lack of coöperation and coördination among the several workers, notably Randall (165), White (227), Carll (27, 28, 29, 30, 31) and Ashburner (5). Lesley (135, 137) offered some suggestions which might have cleared up a few of the misconceptions and miscorrelations, but one is led to suspect that the second State Geologist had too little information based upon personal observations to deal out substantial, constructive criticism. To be sure, much of the work doubtless was hurried, and sub-surface data were far from satisfactory, base maps poor, and accurately determined elevations and intervals scarce. Of all their work, that of I. C. White, done in the extreme northwestern counties of Pennsylvania, was most accurate. Why White worked there and in the northeast, but was not assigned the entire northern tier of counties, is an open question and a detraction from the acumen of those responsible for the direction of the field work of the Second Survey. Had he been permitted to concentrate his studies all along the northern boundary instead of taking up Huntingdon County and the region of the forks of the Susquehanna, principally Northumberland, Montour, Columbia and Luzerne counties, not to mention the work in Pike and Monroe, we may fairly expect that a quite accurate picture would have been left us. But, such was not his assignment; confusion reigned, and decades were to pass before anything resembling a complete study was available, and then largely through research unsupported by state subsidy.

From the early days of the New York Survey, the southwestern or, as it was at first called, the Fourth District, afforded much material for study. Here it was that James Hall really founded his life's work in the Empire State. By 1843, Hall (111) had gone so far as to determine the relations of the type Chemung to the Portage, suggest their relations to the Catskill, and state that, "From the absence of red shales and sandstones forming the Old Red, this rock [the Olean conglomerate] on the west of the Genesee, rests directly upon the Chemung group." He recognized nothing which he called a correlate of the Sub-Carboniferous (Vespertine and Umbral of Rogers) in Pennsylvania. The disappearance of the red beds from the section in southwestern New York proved a stumbling block for years to come. Just so long as the Catskill was regarded as being the *youngest Devonian "formation,"* trouble ensued. Not until it was generally realized that it is actually a "magnafacies" (in the Casterian sense) developed through successfully later stages of continental off-lap from the east and southeast toward the west and northwest, was this bugbear eliminated. Glimmerings of correct understandings came early in the present century with the researches of Clarke (60, 62, 63), Glenn (102) and Butts (18, 20) in southwestern New York and through Butts's projection of this work into the Warren area in Pennsylvania and southward (21).

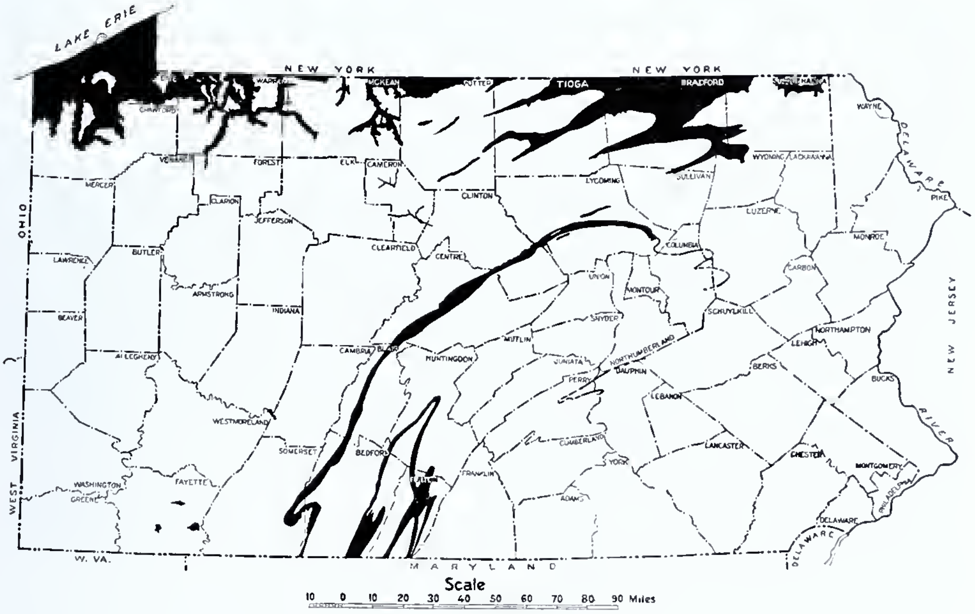


***Figure 66.*—Sketch map showing distribution of Chautauquan stage in Pennsylvania. Because of uncertainty in separating marine Devonian from Mississippian, this map is only approximate in the northwest. Likewise, it is not always practicable to depict in a map of this scale precise limits between marine uppermost Devonian and Catskill continental facies.**

The early years of the twentieth century saw renewed interest in the stratigraphy of northwestern Pennsylvania where work had lapsed since surcease of activities of the Second Survey. The correlation of the oil sands and attempts to tie them in with the stratigraphy of northeastern Ohio brought out new difficulties. It had been correctly observed by I. C. White that the Corry sandstone of Pennsylvania and the Berea of Ohio are one and the same thing. The concept of the presence of marine beds of Mississippian age in northwestern Pennsylvania loomed large before the successive investigators. Butts (20), in his work for the Third Geological Survey Commission of Pennsylvania, reported in 1906-1908 the first really careful attempt accurately to trace formations from the northwest (Warren area) south and southeast, chiefly along the Allegheny River and then across country, to the Allegheny Front region, there to tie in with already known Upper Devonian sections.

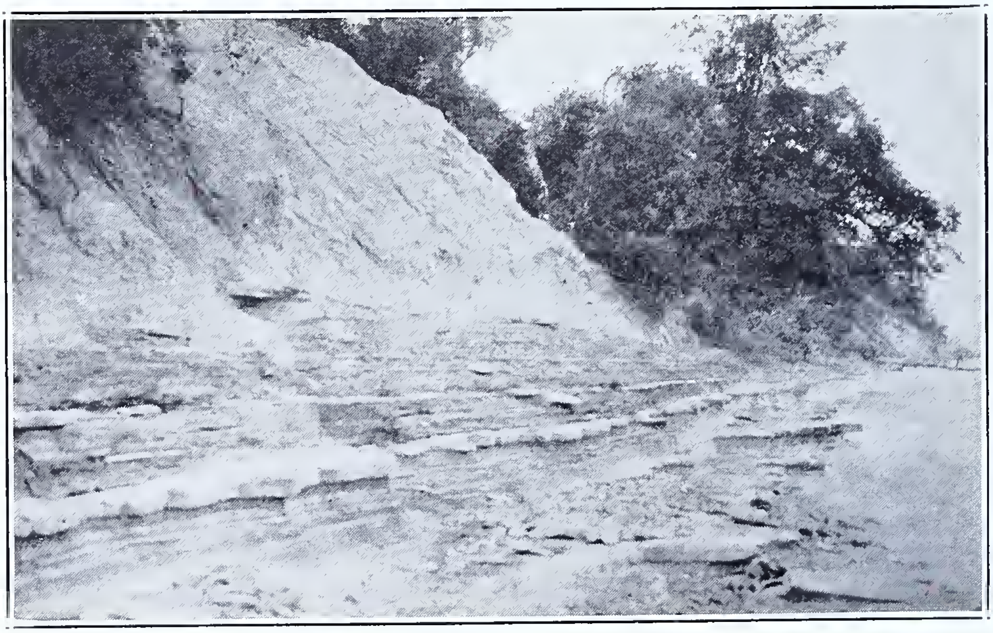
The last two decades have brought out several papers. The term Bradfordian for the supposed Mississippian-Devonian transition beds was adopted and widely used, but now seems likely to be discarded (35). Chadwick (53) and VerWiebe (219, 220) offered suggestions, in part in use today. In 1934 appeared Caster's "The Stratigraphy and Paleontology of Northwestern Pennsylvania" (33). Based upon years of study, this is a useful contribution to the stratigraphy of the region. Unfortunately it devotes many pages to a system of stratigraphic nomenclature of Caster's own, and very little space to thicknesses, comparative sections, and has no geologic map at all. It still leaves much unfinished work for others to undertake. Under the impetus of renewed activity in our oil and gas fields, the Pennsylvania Topographic and Geologic Survey is even now pushing toward culumination its detailed instrumental survey of the northwestern region. Fettke's sub-surface studies and correlations and his work on the Bradford Oil Field (94) are among the results so far published. Cathcart and Fettke have collaborated further in this region; and Cathcart (37, 38, 39, 40, 41, 42 and unpublished data) for several years, has concentrated his work upon the area. Through carefully measured sections and precise mapping, he has produced refinements of correlation which Caster did not give. Because Cathcart's work is thus complimentary to that of Caster, between these parties and others we were fast reaching a clear and complete understanding of the late Devonian and Mississippian stratigraphy of northwestern Pennsylvania when Cathcart resigned from the Survey.

The following table, checked by Cathcart, and compiled from various sources, but drawing largely upon Caster's thesis, supplemented by Chadwick's observations, and personally reviewed by me in the field, attempts to sum up the succession as it now stands for northwestern Pennsylvania's Devonian rocks. As explained farther on, the divisions cited are taken in part from the New York sequences, because all are not fully exposed in northwestern Pennsylvania.

TABLE XXVII, DEVONIAN SEQUENCE IN NORTHWESTERN PENNSYLVANIA AND SOUTHWESTERN NEW YORK

I. C. White, 1881, Erie and Crawford counties	General Succession		
	MISSISSIPPIAN SYSTEM (Basal, according to Caster)		
Riceville shale	Knapp "formational suite"	Knapp conglomerate and shale of authors	
	Kushequa shale member		
	(Marvin Creek limestone zone)		
	DEVONIAN SYSTEM		
	Conewango group		
	Riceville formation		
	Oswayo shale member		
	Roystone coquinite member		
	Venango formation		
	Woodcock sandstone member	Salamanca "formational suite"	Cattaraugus red beds farther east
1st Venango, Salamanca	Tuna-Kilbuck conglomerate lens		
Upper blue shale	Saegerstown shale member		
	Pope Hollow conglomerate		
	North Warren shale member		
2nd Venango Lower shale (red, blue)	Bimber Run conglomerate member		
3rd Venango, Panama, LeBoeuf and Chemung conglomerates to east	Amity shale member		
	Panama conglomerate member (Wolf Creek conglomerate)		
Chemung shale	**Conneaut group** (Chautauquan of Caster)		
	Chadakoin formation		
	Tanners Hill red zone		
	Ellicott shale member		
	Dexterville shale member		
	Lillibridge sandstone member		
Girard shale	Girard formation		
	Girard shale member		
	Cuba sandstone member		
Portage shales	**Canadaway group**		
	Northeast shale		
	Shumla sandstone		
	Westfield shale		
	Laona sandstone		
	Gowanda beds		
	Dunkirk black shale		
	Chemung group		
	Fall Creek conglomerate	Undifferentiated in central Pennsylvania	
	Wellsburg formation		
	Cayuta formation		
	Portage group		
	Fails to come to the surface in the northwestern sections.		

The foregoing table illustrates an early interpretation of the exposed Upper Devonian of northwestern Pennsylvania, and southwestern New York and the present status of the nomenclatorial problem. At the left is the succession as ascertained by I. C. White and published back in 1881 (227). Of all the Second Survey's volumes on our northwestern counties, this is nearest the truth according to modern standards of interpretation. In many respects White's interpretation has been merely elaborated upon, but not vastly improved by subsequent workers. White's divisions are valid and applicable in the region on which he concentrated his work. They become progressively less usable eastward. His Riceville shale includes in its top, beds now thought to belong to the basal Mississippian (Knapp shale, Marvin Creek limestone), and its lower part is assignable to the Devonian system (post-Venango units). White correctly identified the three Venango oil sands and their intervening shales. He erred in correlating the highest with the Salamanca, but the mistake was natural and is a small matter. His use of Chemung shales, was, for that time, valid, as the term Chemung was commonly applied to all post-Portage marine Devonian. The Girard shale is a well-established unit, though his placing it in a bracket equivalent in unit value to Chemung and Portage is illogical. White's designation of the still older shales exposed along Lake Erie as Portage is now discounted as fully as his "Chemung shales." Nevertheless, this correlation, considering the lithology and dearth of fossils in the Canadaway group, was entirely warranted.



Photograph by George H. Ashley

Figure 67. **"Portage" shales of I. C. White, exposed on the shore of Lake Erie, Erie County.**

The right hand column of the table attempts to show the present understanding of the Devonian sequence in northwestern Pennsylvania. It is not necessarily final, and is subject to change, particularly any revision based upon continued work of Cathcart* in this region. It is not to be assumed that this is the sequence of any one section or county, but it is a compilation for the region from, let us say, Potter County west to the Ohio line, plus, for completeness, the Canadaway as exposed along the shore of Lake Erie from Erie County northeastward into New York to the type locality of the Dunkirk black shale at Dunkirk. The marine Chemung gives the subdivisions for that group in south-central New York and north-central Pennsylvania. Occasional notes of synonymy are incorporated in this table, but correlation is largely left for later pages when the matter of the continental Devonian will be reviewed (Chapter VIII).

The major units of the Chautauquan division of the marine Upper Devonian now recognized in part or in their entirety in northwestern, north-central and central Pennsylvania are four, the Conewango, Conneaut, Canadaway and Chemung groups (45, 46, 47, 51, 52). The higher two are practically confined, as far as surface exposures go, to the northwest. The Canadaway as such is probably not typically exposed in its entirety in the State. The Chemung only has been recognized in the large area of marine Upper Devonian of central Pennsylvania embraced roughly between the Allegheny Front and the main Susquehanna Valley. These terms for the major divisions, like all others here applied, are to be considered as still tentative. It is necessary to adopt some sort of nomenclature for the sequence, and those proposed by Caster (*op. cit.*) in Pennsylvania and Chadwick (*op. cit.*) in New York are the basis for that here employed.† In his papers, "Chemung is Portage" (52) and "Faunal Differentiation in the Upper Devonian" (51), Chadwick has set down what appears to be a reasonable basis for distinguishing these groups. His statement "Chemung is Portage" may be a misleading reiteration of what James Hall noted and plainly described nearly a century ago. The name Chemung is not synonymous with the name Portage, although Chadwick's equivocal title might cause one to think them so. Actually, the Chemung in its type locality is a continuation upward from the Senacan (Portage) of the arenaceous marine "magnafacies" of the Upper Devonian; and, instead of being synchronous with the Portage, it is merely a continuation of earlier established neritic conditions. The two, Chemung and Portage, are faunally distinguishable. The correlation westward of these sandy beds with the pelitic "magnafacies," the Naples and superjacent shales, has been changed so often recently, chiefly through Chadwickian vacillations, that one is tempted to abandon the whole problem in disgust. Nevertheless, allowing that Chadwick's faunal lists for the groups are correct, in them there is a valid and convenient means of distinguishing the four Chautauquan groups. Furthermore, there are lithic data to substantiate the faunal. These will be cited in due time. In fact, aside from my doubt as to the final correlation, there is little reason for not accepting his classification of major units. I am using Conneaut Group (Chadwick) rather than Chautauquan, in the restricted sense redefined by Caster, because I believe the former term is less likely to cause confusion. In redefining Chautauquan in a narrower sense, Caster uses a term which is of long standing and has come to be recognized as including all the post-Portage Upper Devonian. I prefer to keep it unrestricted and use it in this sense, as it thus fills a place where there is definite need for such a term, the Chautauquan division.

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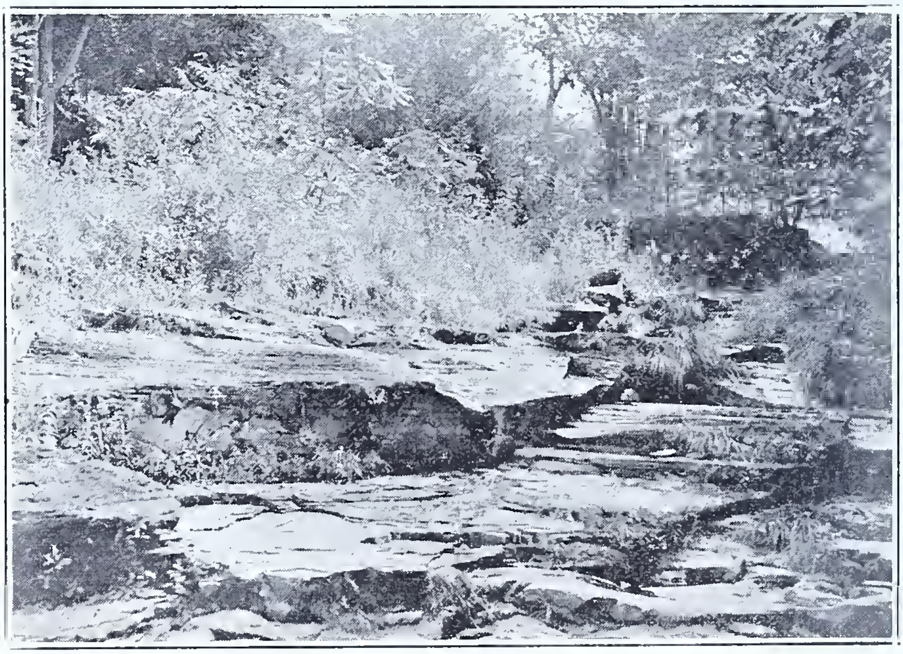
* S. H. Cathcart resigned from the Pennsylvania Geological Survey in October 1937.

† Actually, there is no guarantee that these terms will stand. When the bickering is over, perhaps a totally different set of names for this inoffensive sequence will be foisted upon us.

Chemung Group

The lowest of the four groups comprising the Chautauquan division of the Upper Devonian is the Chemung. With the First and Second Pennsylvania Geological Surveys, the Chemung was a case of mistaken identitfy. As pointed out in describing the Portgage group, the two, Portage and Chemung, were invariably confused. Probably this is largely to be traced to misunderstanding James Hall, who in 1843 pointed out that the type Chemung at Chemung Narrows, New York, is to all intents and purposes a continuation lithologically and faunally of the Portage sandstones. Hall (111) said, "It may thus happen that the fossils so typical of the Chemung group commenced their existence in the eastern part of New York much earlier than in the western part; and, therefore, the strata equivalent in age to the Portage group may there contain fossils which at the west appear at a much later period." No truer word was ever spoken, but Hall did distinguish the Chemung fauna from the Portage. Had my more recent predecessors of the Second Survey in Pennsylvania followed



Photograph by Bradford Willard

Figure 68. **Chemung shale, near Susquehanna, Susquehanna County.**

Rogers in working out their own salvation through an independent system of nomenclature instead of trying to adopt and adapt the yet unfinished New York system, they might have made a more enviable record. The Second Pennsylvania Survey geologists sometimes thought they knew the difference between Chemung and Portage, but usually their distinctions fail to stand the test. A single instance is I. C. White's glaring error in reporting Chemung in Monroe County (228). To him *"Spirifer" disjunctus* and *"Spirifer" mesatrialis* were indistinguishable.

Distribution and thickness. The marine beds of Chemung age in Pennsylvania overlie the Portage group (Trimmers Rock sandstone, Parkhead sandstone or Brallier shale) throughout most of central Pennsylvania, that is, the region between the Allegheny Front and the Susquehanna River and south to the Maryland line in Bedford and Fulton counties. They also crop out sporadically along the North Branch of the Susquehanna to the New York line, particularly in Susquehanna County and westward. The "Chemung" which I reported on Chestnut Ridge in southwestern Pennsylvania is perhaps younger (237, 248).

The thickness varies from zero on a line drawn from Dauphin County north to Northumberland and east to Luzerne County to a maximum of 3,000 to 3,400 feet along the Allegheny Front between Altoona (the Horseshoe Curve section) and Lock Haven along the West Branch of the Susquehanna. These figures take partial cognizance of the recurrent Chemung faunules in the lower portion of the continental red beds. (See Figures 70 and 93.)

Limits, character, fauna and correlation. The Chemung group in south-central New York and adjacent Pennsylvania consists of the following divisions:

Wellsburg formation:	thin-bedded sandstone and shale to flaggy sandstone and coquinite lenses. Fall Creek conglomerate locally at top.
Cayuta formation:	drab to bluish shale and thin sandstones.

In Maryland the Chemung group is called the Chemung sandstone member of the Jennings formation (143), of which it is the highest division. Below, it is reported to intergrade faunally and lithogically with the Parkhead sandstone which is different chiefly in lacking *"Spirifer" disjunctus.* The upper limit of the Chemung in Maryland is drawn wherever the Catskill red beds appear. The Maryland Geological Survey does not recognize the Wellsburg or Cayuta formations, but sub-divides the Chemung into:

5. Upper shale and sandstone beds
4. Upper conglomerate
3. Middle shale and sandstone beds
2. Lower conglomerate
1. Lower shale and sandstone beds

Comparing these and their faunas with the New York sequence as recorded chiefly by Williams (263, 266), number 1, is Cayuta in age as too are probably the lower conglomerate and number 3. In this the Parkhead is taken to be of Enfield age. The remainder, numbers

4 and 5, are thus of Wellsburg age*. These affinities are based partly upon observations of the Pennsylvania sections intermediate between New York and Maryland. The faunas and lithology of the Chemung in central Pennsylvania show a trend toward the Maryland conditions as traced south, and toward the New York sequence as studied northward. For this reason, exact correlation with the typical New York sequence is rendered increasingly difficult southward.

Everywhere, the base of the Chemung group in Pennsylvania is drawn at the lowest appearance of "*Spirifer*" *disjunctus.* This and only this criterion is generally available, since in most sections there is no marked lithologic change upon which to separate the Chemung and Portage groups. While "*Spirifer*" *disjunctus* ushers in the Chemung, it may not be designated a Chemung guide fossil, for it is known that its vertical range extends well above the group. Either it or closely related mutants continue even into beds assigned to the Lower Mississippian. Chadwick (71) characterizes the Chemung fauna by the presence of:

Stropheonella coelata
Douvillina mucronata (cayuta auct.)
Leptostrophia nervosa
Dalmanella carinata
Atrypa aspersa (spinosa)

Pterinea chemungensis
P. reversa
Byssopteria radiata
Goniophora chemungensis

He has cited a still longer list of fossils which appear to be confined to the true, restricted Chemung, but the above list is sufficient.

In general, the Chemung is characterized by olive or olive-brown, often gnarly sandstones and olive or gray shales. This lithology is indistinguishable from the subjacent Trimmers Rock sandstone with which it forms the neritic "magnafacies" of the Upper Devonian marine off-lap deposits of central Pennsylvania. Similarly, it is distinguished from the Parkhead chiefly by fossils, but here there does seem to be some lithic dissimilarity. In Bedford and Fulton counties what is taken to be a northward continuation of the Parkhead member of Maryland is rather massive sandstone which may carry pebbly beds and true conglomerate. The overlying Chemung is dominantly sandstone in which vast quantities of *Ambocoelia umbonata* (or *gregaria*) occur, a condition strictly in accord with that observed in southern New York and northern Pennsylvania.

The following faunule was taken near Bedford in Bedford County and illustrates clearly the biologic character of the basal Chemung in south-central Pennsylvania. In this instance, as is usual in these parts, "*Spirifer*" *disjunctus* is very rare, and *Ambocoelia umbonata* is abundant:

Crinoidea, columnals
Leptostrophia interstrialis (Vanuxem)
Douvillina cayuta (Hall)
Productella lachrymosa (Conrad)
P. speciosa Hall
Schizophoria striatula (Schlotheim)

Atrypa reticularis (Linnaeus)
"*Spirifer*" *disjunctus* Sowerby
"*S.*" *mesacostalis* Hall
Ambocoelia umbonata (Conrad)
Pterinea interstrialis Hall
Pelecypod, indet.

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* Because *Athyris angelica* is reported from number 5 only and at but one locality in Maryland, post-Chemung marine beds are essentially absent in that State.

For comparison with the above, note the following Parkhead faunule from Cove Creek Valley in southern Fulton County:

Crinoidea, columnals
Chonetes scitulus Hall
Liorhynchus ?
Camarotoechia congregata var. *parkheadensis* Clarke and Swartz
C. horsfordi (Hall)
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *mesastrialis* Hall
"*S.*" *mucronatus* var. *posterus* Hall and Clarke
"*S.*" *marcyi* var. *superstes* Clarke and Swartz
Grammysia subarcuata Hall
Actinopteria sp.
Cypricardella sp.

In Perry County the supposed Parkhead is chocolate-colored sandstone. From its color and position, practically at the base of the Chemung age red beds, it presents conditions analogous to those under which the Chadakoin (mentioned below) formed, but is, of course, much older. Where the Chemung overlies the Brallier shale, the lithologic inequality readily distinguishes the two. In explanation I repeat, that the Chemung lithologically is nothing more or less than a continuation of the Trimmers Rock arenaceous phase of the Portage group, that is, the neritic "magnafacies" of the Upper Devonian marine beds which laps westward and northwestward over the Brallier shale, the peltic "magnafacies."

The definition of the top of the Chemung is quite another question. In southwestern New York, Chadwick, in his latest utterance, has drawn it at the base of the Dunkirk black shale. Farther east, the Fall Creek conglomerate is taken to be the highest unit of the Chemung (Chadwick suggests it is slightly younger). From its type locality in northern Bradford County, this conglomerate is supposed to extend into New York State. The Dunkirk black shale and Fall Creek conglomerate are wanting in central Pennsylvania as stratigraphic criteria for determining the top of the Chemung. Likewise, the Wellsburg and Cayuta formations of the New York Chemung, probably present in northeastern or north-central Pennsylvania, have been dubiously distinguished in the great body of Chemung age sandstones and shales in the central part of the State. There, any subdivision or correlation is largely founded upon faunal data. Even these are sometimes obscure because of changes southward. In the section above Lock Haven what was taken to be the "Third *Tropidoleptus* zone" of Williams (266) should, if correctly identified, establish the approximate base of the Wellsburg.

The following fauna from this section illustrates this point:

Aulopora?
Crinoidea, columnals
Fenestella sp.
Bryozoa, indet.
Lingulella sp.
Leptostrophia interstrialis? (Vanuxem)
L. sp.
Douvillina cf. *cayuta* (Hall)
Schuchertella chemungensis (Conrad)
Productella lachrymosa (Conrad)
Dalmanella tioga (Hall)
Schizophoria striatula (Schlotheim)
Camarotoechia eximia (Hall)
Liorhynchus mesacostale Hall
Tropidoleptus carinatus (Conrad)
"*Spirifer*" *disjunctus* Sowerby
"*S.*" *mesacostalis* (Hall)
Ambocoelia umbonata (Conrad)
Palaeoneilo sp.
Pterinia chemungensis (Conrad)
P. chemungensis? (Conrad)
P. sp.
Pelecypod, indet.
Fucoids

Nowhere in central Pennsylvania has the presence of any marine Devonian later than the Chemung been proved. In other words, throughout the central part of the State, the continental Catskill facies everywhere became the dominant form of sedimentation and overlapped the marine before the close of Chemung time; not so in north-central Pennsylvania. The presence of post-Chemung marine beds is well established there, for the advent of *Athyris angelica*, found in Tioga and Bradford counties, etc., marks the beginning of the beds assigned to the Canadaway group. In this, Chadwick's definition is accepted.

I reported Chemung in southwestern Pennsylvania, particularly in Fayette County on Chestnut Ridge east of Uniontown, in the Conemaugh gorge west of Johnstown (237). In Fayette County, the southwesternmost known exposures of marine Devonian in Pennsylvania are found on Chestnut Ridge (195, 196, 197, 149). Fossiliferous beds are capped by pebbly strata assigned to the Pocono with no Catskill red beds between. West of Johnstown in the Conemaugh gorge the relations are similar on the west flank of the Laurel Hill anticline, but on the east flank some red beds occur underneath the Pocono. Since working there, and publishing my account, additional data have come to my attention, but I am inclined to hold to my original idea. Caster (248), however, is of another mind, contending that the marine Devonian, particularly on Chestnut Ridge, is somewhat younger. Granting that some of the fossils, as he states, indicate that the beds may belong to the Conewango, there is also present an element suggesting the pre-Chemung, Parkhead fauna of Maryland. While I admit that Caster's suggestion is valuable and is reasonable if based solely upon northwestern Pennsylvania conditions, I still hold that my original suggestion is just as plausible. The fauna, containing elements of both pre- and post-Chemung significance, lies geographically intermediate between places where the Parkhead (older, to southeast) and Conewango (younger, to northwest) are exposed. Supposing the usual northwestward off-lap to have taken place, we might assume a progressive faunal change with dropping out of older and acquisition of younger elements successively. These faunas did not arise through "spontaneous generation," but lived long and migrated far. The lithology supports such a theory. Being a way station, we might reasonably expect that on Chestnut Ridge the fauna of the true Chemung could contain mingled elements of both younger and older groups. If, as some suppose, there is a marked Devonian-Mississippian disconformity over a considerable part of southwestern Pennsylvania, this supposition is further upheld through the probable absence of the highest marine Devonian. The occurrence of red beds in the Johnstown section is further evidence of greater antiquity and progressive off-lap, as the red is unrecorded from the Conewango of the northwest.

The Canadaway Group

The Canadaway group has been defined by Chadwick as follows:

> To the pseudo-Chemung, later beds, from the base of the Dunkirk to the base of the Cuba sandstone, the writer proposed to apply the substitute and distinctive name, CANADAWAY GROUP. . . .

> On Canadaway Creek the members of this group are (a) Dunkirk black shale, (b) Gowanda beds, formerly Portland (preoccupied), (c) Laona sandstone, (d) Westfield* shale, (e) Shumla sandstone, (r) Northeast shale, the "Portage" of Erie County, Pa. On the Genesee River, the Dunkirk is passing into the Canaseraga sandstone phase, sometimes included in the Prattsburgh sandstone still farther east; the Gowanda assumes a "Chemung" facies, locally the Caneadea shale; the Laona and Shumla combine into the Rushford sandstones; the Northeast has long since become the Machias beds of "Chemung" facies." (52, 51)

Thus, the Canadaway group overlies the Chemung. From Chadwick it seems that the Dunkirk or its equivalent eastward includes the Fall Creek conglomerate, but this correlation seems doubtful. I shall simply say that the group is included between the base of the Dunkirk and the base of the Cuba. It is, of course, the succession to which I. C. White applied the misnomer ''Portage shales.'' It is divided in southwestern New York and on into northwestern Pennsylvania into five units:

Northeast shale
Shumla sandstone
Westfield shale*
Laona sandstone
Gowanda beds
Dunkirk black shale

As quoted above, these gradually pass eastward into the coarser clastic deposits of the neritic ''magnafacies'' which immediately succeeds the lithologically similar, faunally district, true Chemung. The thickness ranges from about 400 in the shaly to 800 feet in the sandy facies of the Canadaway. The shales of the Canadaway groups are not fully represented in Pennsylvania at the surface, but in Bradford and Tioga counties sandier beds assigned to the Canadaway are known. These rest to the east upon the Chemung, from which they are distinguished principally by the appearance of *Athyris angelica* and *Productella lachrymosa* var. *stigmata.* Chadwick, again, has furnished a long list of what he considers diagnostic species of this group. Locally, particularly in Bradford County the Luthers Mill coquinite and similar, closely related beds appear in the top of the New Milford group of sandy beds whose lower part is of Chemung age. The coquinite is believed to mark quite closely the base of the Canadaway. A characteristic Canadaway faunule from Bradford County (Franklindale Narrows) reads (*Cf.* p. 292):

Crinoidea, columnals
Stropheodonta demissa (Conrad)?
Schuchertella chemungensis (Conrad)
Productella lachrymosa var. *stigmata* Hall
Camarotoechia sappho Hall
C. stevensi Hall
C. contracta Hall
C. sp.
Cryptonella eudora Hall
"Spirifer" disjunctus Sowerby
"S." mesacostalis Hall (may be *S. williamsi)*
Athyris angelica Hall
Grammysia elliptica Hall
Sphenotus contractus Hall
Leptodesma propinqua Hall
L. orcus Hall
L. becki Hall
L. sociale Hall
Schizodus sp.
Orthoceras sp.
Pisces, undetermined spines

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* This name appears to be preoccupied.

Throughout this region of eastern Bradford and western Susquehanna counties, the Canadaway beds are passing over eastward and upward into the continental facies. Therefore, hereabouts, the Canadaway can be but roughly delimited. Its upper boundary would be quite obscure were it not for the fact that the Cherry Ridge red member to the east can be traced westward above the Honesdale as the latter, a gray-green continental member, changes to Canadaway marine sediments westward. The Cherry Ridge red beds are here (Bradford County) closely equal to the so-called Cattaraugus of northern Tioga County, which itself rests upon marine strata called "Chemung" by authors, but probably of late Canadaway age. However, the age of the base of the Cherry Ridge or, westward, the Cattaraugus, is rising, so that in western Potter County the basal red beds probably are of early Conewango age and in the eastern part of that County are assignable to Conneaut.

Just where the top of the Canadaway may pass below ground westward is uncertain, but presumably this takes place somewhere in Potter County. The maximum thickness of the Canadaway may be 500 to 600 feet in Tioga County.

Conneaut Group

The Conneaut group 51 and 52 embraces the beds which reach from the base of the Cuba sandstone to the base of the Wolf Creek (or Panama) conglomerate. In these, the fauna of the preceding Canadaway has been modified by loss of *"Spirifer" mesacostalis* and accession of *Camarotoechia* (?) *duplicata*. Chadwick lists many supposedly characteristic fossils, but the above mentioned faunal change seems to define the base of the group. This is the group that Caster (33) called by the redefined and restricted name Chautauquan, a matter already discussed in the present report. Beds of probable Conneaut age are found in Potter County below the base of what is called the Cattaraugus red shale. The base of the Conneaut is often doubtfully drawn. for the Canadaway and Conneaut have not always been satisfactorily separated because of the failure to find diagnositic fossils and the absence of the Cuba sandstone. East of McKean or western Potter County, the Conneaut is obscure. But from that region westward what I take to be a remnant of the Cuba sandstone marks the lower limit of the Conneaut group.

Caster (33) has divided the group into several minor unts distributed among the Chadakoin formation ("stage" of Caster) above and the Girard formation ("stage") below. The latter is composed of I. C White's Girard shale and the underlying Cuba sandstone which marks the bottom of the Conneaut group. The Chadakoin is a shaly member at whose base Caster places the Lillibridge sandstone; at the top of the local Tanners Hill red zone (of Butts 21). The literature records the Chadakoin as the "pink rock" of drillers. At the surface, these beds may be plum or chocolate. However, the color has little correlative or diagnostic significance, as the late Devonian marine beds generally assume such a shade in passing over into the continental facies, so that the condition may be duplicated in strata ranging from the Portage up in Pennsylvania. This has already been cited in describing the color of the supposed Parkhead in Perry County.

The thickness of the Conneaut group, based upon the interval between the bottom of the Panama conglomerate and the bottom of the Cuba sandstone, is approximately 525 feet. The beds of this group are not clearly distinguished east of McKean County, and are best developed west of it.

Conewango Group

The last marine division of the sequence of the marine Devonian of northwestern Pennsylvania is the Conewango group. The name appears to have been first proposed by Charles Butts (21) in the Warren area for marine beds equal to the Oswayo and Cattaraugus farther east, and as so applied was equivalent to the lower part of the Riceville and the Venango group farther west as determined by I. C. White. Butts's definition is retained unaltered. In northwestern Pennsylvania, the base of the group may be recognized by the Panama conglomerate (3rd Venango oil sand). The base of the Knapp conglomerate approximately mark its top. Paleontologically, Chadwick furnishes a long list of "diagnostic fossils." He cites the following genera as apparently confined to the Conewango: *Tylodictya, Mytilops, Pegasella, Palaeanatina, Prospiraxis, Ganorhynchus, Apedodus and Thinopus.* The last of these Caster is inclined to consider Mississippian (quoted in 241).

Like the preceding Conneaut, the Conewango group is not easily distinguished eastward as the Panama dies out. Although the Oswayo and the Cattaraugus are persistent, the former loses its marine contents, and the latter thickens downward and cuts into older marine beds. As the group becomes fully marine westward, it is separated into two formations ("stages" of Caster). Above is the Riceville which is essentially marine Oswayo with a fossiliferous band, sometimes a coquinite, at the base, well developed in the neighborhood of Bradford. Below is the Venango formation. This contains a number of lesser units. Among them are three prominent sandstone or conglomerate bands, the Woodcock at the top, Pope Hollow and Bimber Run (Salamanca, in part, of authors) in the median part and the Panama at the base. These are the First, Second and Third Venango oil sands, respectively, of I. C. White and most reports on northwestern Pennsylvania. They are separated by certain shales as noted in Table XXVII, page 246. A thickness of approximately 300 feet can be assigned the group in Pennsylvania from Warren County westward.

DEVONIAN-MISSISSIPPIAN CONTACT

Almost with the first studies of the stratigraphy of northwestern Pennsylvania and southwestern New York and northeastern Ohio controversy raised its head as the position of the top of the Devonian came under question. The later marine sequence below the Olean conglomerate may not be readily separable upon fossils, structures or lithology into units assignable to the Devonian and Mississippian systems respectively. Early tendencies placed the upper boundary of the Devonian at the base of the Olean conglomerate (basal Pennsylvanian), assigning thereby all the marine complex below it to the "Chemung". During the years that have intervened since these early investigations, the position of the contact has fallen and risen as the tide of opinion ebbed and flowed with the whims of the several investigators. The realization that the non-marine sub-Carboniferous represented the Mississippian as a vast thickness in the anthracite fields and thinned northwestward, and also that that system was highly developed as marine strata in the Mississippi and Ohio valleys, led to the belief that some of the beds of northwestern Pennsylvania could be assignable to that system. This complicated the matter by introducing not one boundary, as between the Devonian and the basal Coal Measures, but two, the Devonian-Mississippian and the Mississippian-Pennsylvanian. The latter was readily established and generally agreed upon as coming at the base of the Olean. The former has caused endless argument. Because of this difficulty, Girty (101) introduced the term Bradfordian for rocks which presumably were transitional between the two systems, a use in part analogous to I. C. White's Riceville shales. Apparently much can still be said in favor of this use, but at present opinion's pendulum has swung to the opposite end of the arc, and those purporting to be best informed would have us believe in a sharp break between the Devonian and the Mississippian. The ghost of the Bradfordian may not have been successfully laid by Caster with the concurrence of Chadwick and Torry, but for the present I am inclined to accept Caster's views. Nevertheless, what break there is, is really quite trivial both faunally and lithologically so that perhaps in northwestern Pennsylvania we come as near to a Devonian-Mississippian transition as can be expected. I agree with Lesley who long ago expostulated in scathing denunciation on the confining artificiality of our systemic terminology.

Briefly, the post-Devonian succession in northwestern Pennsylvania, that is, the beds above the Conewango group (Oswayo shale) as used in this book, may be summarily abstracted as follow (adapted from Caster, 33):

TABLE XXVIII. POST-DEVONIAN SEQUENCE OF NORTHWESTERN PENNSYLVANIA

PENNSYLVANIAN

- Olean conglomerate (Sharon, Garland, Pottsville of authors)
  - Disconformity

MISSISSIPPIAN

- Kinderhook group
  - Crawford formation
    - Hempfield shale member
    - Shenango sandstone member (sub-Olean conglomerate)
  - Meadville formation
    - Upper shale
    - Upper limestone
    - Lower shale
    - Lower limestone
  - Sharpsville formation
  - Orangeville formation

- Oil Lake formation
  - Corry sandstone (Berea)
  - Cussewago shale and limestone
  - Knapp conglomerates and shale
  - Kushequa shale
    - (Marvin Creek limestone)
- Disconformity

Two points upon which there is general agreement today are (1) there is a great unconformity at the base of the Olean representing a large part of Mississippian time; and (2) the Corry sandstone of northwestern Pennsylvania and the Berea sandstone of northeastern Ohio are correlates. Furthermore, there seems little doubt that Butts was basically correct in believing that the Burgoon or upper Pocono is cut out by the Pennsylvania-Mississippian unconformity in the northwest, leaving no equivalent of the upper (and perhaps middle) Pocono and the entire Mauch Chunk formations of the anthracite fields of northeastern Pennsylvania. That the Corry or Berea and the Knapp conglomerates are to be correlated with some parts of the Pocono is a reasonably established fact. My own observations on the Knapp and attenuated Pocono northwest from the Allegheny Front convince me that the Knapp is the thin remnant of the massive lower Pocono, and that the Corry must, if indeed it is truly distinct from the Knapp, come in a little higher, but should equal part of the same lower Pocono member. In this I agree with Butts in correlating the Berea with the lower part of the Pocono.

In describing the continental Devonian the evidence of a disconformity at the base of the Pocono will presently be demonstrated. This evidence is drawn from analogy and correlation with the situation as recognized in northeastern Pennsylvania, and that this disconformity becomes more pronounced westward. In the northeast this is between beds wholly of continental origin, the gray Pocono and the red Catskill (Mt. Pleasant red shale). The continental succession adjacent to the contact is:

MISSISSIPPIAN	Pocono formation Griswold Gap conglomerate locally at base
DEVONIAN	Mt. Pleasant red shale Elk Mountain gray sandstone

The Griswold Gap is probably local and confined to the east. The Mount Pleasant red shale pinches out westward, bringing the Pocono and Elk Mountain into contact. The Elk Mountain apparently becomes the Oswayo, and the basal Pocono seems to pass over into Knapp, Berea and Corry. Such is my interpretation. It will be further discussed in the next chapter on the continental Upper Devonian formations.

Caster* has shown that just below his Knapp "formational suite", as he calls the Knapp conglomerates and associated shale, comes the "Kushequa shale" with the "Marvin Creek limestone zone" in its base. These beds rest in disconformity upon the Conewango group, the highest number of which is the Oswayo. Adapting from him (33) the succession runs:

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* Detailed stratigraphic work in northwest Pennsylvania in connection with oil and gas studies now in progress has already raised some questions regarding Caster's conclusions, and when completed may lead to some modifications of his section. See Fettke, Bradford Oil Field: Topo. & Geol. Survey of Pa., vol. M 21, 1938, pp. 30 and 33.

MISSISSIPPIAN
  Oil Lake group ("series" of Caster)
  ....
    Knapp "formational suite"
    Kushequa shale member
      (Marvin Creek limestone zone)
    Disconformity
DEVONIAN
  Conewango group
    Oswayo shale

Since the Oswayo equals the Elk Mountain, according to my findings, and the Knapp probably equals the lowest Pocono, and the Cherry Ridge of northeastern Pennsylvania is neither itself present nor represented by any marine correlate but pinches out westward from its type locality in Wayne County, I agree with Caster that there is physical evidence for a break at this point, the top of the Oswayo. This concept Caster has supported by careful comparisons of the faunas above and below the contact. Of it he says (33; p. 102):

> Faunally the Oswayo belongs with the Devonian, as is elsewhere explained in this paper. A minor disconformity occurs at the top of the Oswayo, and above this sedimentary accumulation was renewed under much the same type of conditions as had existed during Oswayo deposition. However, a Mississippian fauna is preserved in the Oil Lake strata on the younger side of the disconformity. Mississippian fossils are absent in the Oswayo member.

Tabulating, we have

NORTHWESTERN PENNSYLVANIA	NORTHEASTERN PENNSYLVANIA
Mississippian	Mississippian
Knapp conglomerate, etc.	Lower Pocono formation
Disconformity	Disconformity
Devonian	Devonian
....	Mt. Pleasant red shale
Oswayo shale	Elk Mountain sandstone

Doubtless there are other "breaks". A more spectacular one as far as physical evidence goes, separates the Oswayo from the Cattaraugus near Bradford, Pennsylvania, but it is clearly local, and faunal evidence does not support the supposition that this may be of inter-systemic value. More will be said of the Devonian-Mississippian relations and the line of separation of these systems in the next chapter. For the present, after sifting the evidence, my personal feeling is that the Knapp may be looked upon as approximating the base of the Mississippian in northwestern Pennsylvania according to recognized usage of the term Mississippian System.

Because the problems embracing the Devonian-Mississippian boundary, the marine sequence, and the correlation of the higher Devonian in Pennsylvania are so closely related to the Catskill continental facies, further discussion of these will be found in the following pages, Chapter VIII. This is particularly true of the Devonian-Mississippian contact and of correlations between the various subdivisions of the Chautauquan and the corresponding, continental units of the Catskill insofar as these are recognized in Pennsylvania.

CHAPTER VIII

CATSKILL CONTINENTAL FACIES

What Is the Catskill in Pennsylvania?

Even before the recognition and naming of the Devonian system by Sedgwick and Murchison in England a century ago, the name Old Red Sandstone had taken its place in geologic literature. Used in contradistinction to the New Red Sandstone of Permo-Triassic age, it was applied to widespread deposits of red sandstones and shales which occur between the Silurian and the sub-Carboniferous in the British Isles. Its equivalence to the marine Devonian of southwestern England was established by Sedgwick and Murchison. The lithic term, Old Red Sandstone, found early application in North America. It was used by Maclure in the eastern United States, including Pennsylvania. Doubtless, his usage was inaccurate, for it is improbable that he distinguished between our several red units now assigned respectively to the Ordovician, Silurian, Devonian, Mississippian and Triassic systems. Nevertheless, this appears to be the first application to the geology of Pennsylvania of a name now universally recognized as referring to a part of the Devonian system (144, 145).

Rogers recognized in these red rocks part of the ninth division as used in his Annual Report for 1836 (171), and in 1838 (172), in the Second Annual Report designated them as ''Number IX,'' 6000 feet of ''Red shales and argillaceous red sandstones, also brown, gray, greenish and buff coloured sandstones''. He noted that they ''are remarkable for a deficiency of fossil shells and other marine animal remains''. The first State Geologist for the Commonwealth traced their distribution and in some respects showed the clearest perception of the region of outcrop of these red beds that has appeared for nearly a century. As usual, Rogers professed an aversion to ''imported names''. Instead of using Old Red Sandstone or adopting the newly applied New York name Catskill, he coined his own, ''Ponent Series'', which became official in ''The Geology of Pennsylvania, 1858'' (177). The Ponent was synonymous with Formation IX; Ponent is forgotten now, but Formation IX has survived even to our present day and generation.

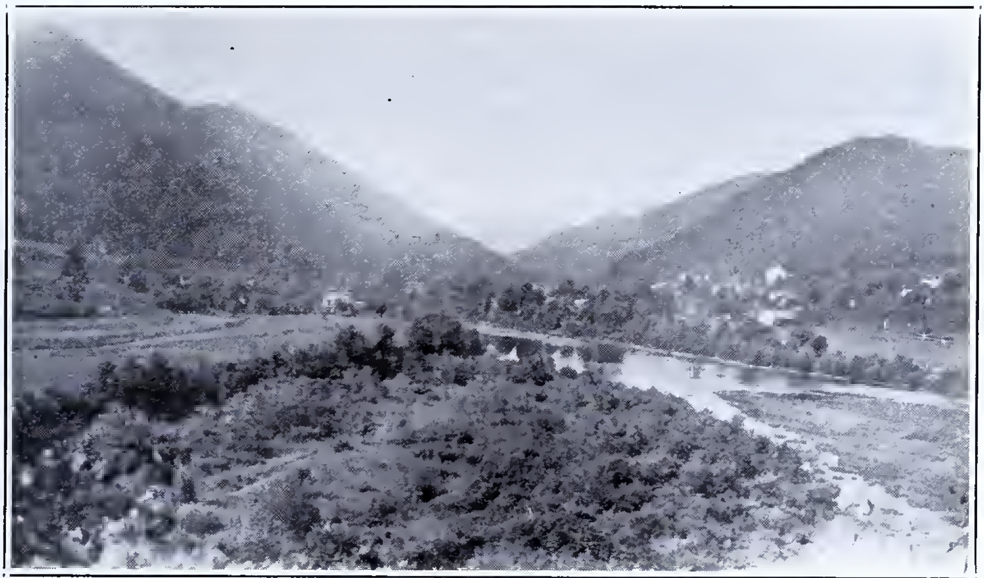
The Second Geological Survey of Pennsylvania generally retained Rogers's use of roman numerals for large divisions of the Paleozoic. but adopted also the New York name Catskill for the Devonian red beds. It is not my purpose to enter into a discussion of the origin and use of the name Catskill in New York. Its long and intricate history has been presented recently by Chadwick (48, 54) through the medium of the New York State Museum. Presuming his data to be correct for New York, I am disinclined to comment further, except to remark that when mention is made by him of the use of Catskill in Pennsylvania, it is regrettable that so much that is inaccurate or misleading should have been allowed to appear under the stamp of approval of an official publication. In the pages to follow, I shall give as accurate an account of the Catskill in Pennsylvania as our present knowledge permits. Errors there must be, and the next generation of geologists may completely revise my theories and explanations. Nevertheless, this I may truly say, that what is here stated is drawn, not from admittedly inaccurate and inadequate, out-of-date publications supported by a mere, cursory glance at the field, but it is primarily based upon my own field observations extending over several years and is supplemented by the recent work of other students in this area. What errors there are cannot, therefore, be attributed to mistakes of a past generation of geologists, but to misunderstandings by the present-day workers.

Meaning of Catskill. As used in this paper, the name Catskill must suffer some modification from its earlier uses in New York, nor is it necessarily in precise agreement with the accepted definition of the term today at Albany. The Catskill is a facies term, and facies variations may render a precise and delimiting definition of it in one locality inapplicable in another. It is truly a *magnafacies,* using Caster's pertinent terminology. As such it may be defined broadly as the continental magnafacies of the Devonian. It is divisible in Pennsylvania into several clearly separable and distinct units. These are all well-exposed and typically developed. Their relative ages are fixed through the fact that in practically all cases they are traceable into fossiliferous marine beds. Many of these divisions, known and named by I. C. White (226, 228, 229), are of long standing and have a well-established place in the literature. Because of their distinctness, mapability and the accuracy with which their ages may be ascertained and their correlations established, they take precedence over any other system of Catskill terminology previously misapplied to Pennsylvania. In this I refer specifically to that of Chadwick, which I at one time attempted to use here (236, 237). No doubt some of his divisions are valid; some may even be close correlates with mine in Pennsylvania. Certainly, those drawn from the section in the Catskill Mountains have no place in the nomenclature in Pennsylvania's continental Devonian sequence.

Before proceeding, it is necessary to introduce one qualifying statement regarding my application of Catskill. I have in so far presumed to trespass as to include in my studies the important but neglected area of the Green Pond Mountain syncline of north-central New Jersey. There, I have been able to obtain supplementary data on older Catskill beds than are usually found in Pennsylvania. As a complement to my work, these have proved invaluable, but as far as their effect upon the interpretation and understanding of the Catskill go, the New Jersey data have served to strengthen my position and tenets (236, 257, 250, 245).

General character of the Catskill. The Catskill continental facies of the Devonian in Pennsylvania and north-central New Jersey is at first glance monotonous. To one superficially interested, there is merely a vast succession of red beds. Actually, this mass of continental strata, dominated by red sandstone and shale, varies surprisingly.

Conglomerates are common, some both heavy and coarse. Calcareous beds are known. There are several thick, non-red, gray or greenish units of wide areal distribution. Fossils are rare, to be sure, but plants there are sometimes even in sufficient quantity to have produced coal laminæ. Animal remains are chiefly those of ostracoderms. Invertebrates are almost unknown. Since the Catskill is defined as a continental facies, the inclusion of marine fossils would be paradoxical. Nevertheless, marine incursions are found, usually relatively high in the red beds, and here and there red shale itself may carry salt-water invertebrates. These incursions recur intermittently, but are an invaluable means of dating the lower part of the facies.



Photograph by George H. Ashley

Figure 69. **Valley of Lycoming Creek, view north from mouth. The Catskill is the surface rock in much of the Allegheny Plateau and is exposed along such valleys as this where deeply entrenched streams transect the nearly horizontal strata.**

Distribution, Thickness and Limits

Distribution.—Catskill continental rocks are exposed over a greater area in Pennsylvania than any other major Devonian unit, we may almost say of the entire remaining Devonian. They occupy essentially all of the northeast corner of the State, forming the surface rocks of all or the greater parts of Tioga, Bradford, Susquehanna, Wayne, Pike, Monroe, Wyoming and Sullivan counties. They are a dominant feature in Potter, Lackawanna, Luzerne and Lycoming counties. The Catskill extends in a broad band through the folded Appalachian chain across Carbon, Schuylkill, Lebanon and Dauphin counties and then weaves back and forth across the Susquehanna and Juniata valleys. The red beds form the slope below the scarp of the Allegheny Front and extend south into Maryland, with lesser bands to the east, particularly about the Broad Top coal field in Huntingdon, Bedford and Fulton counties.

Thickness.—As may be expected of a great body of continental beds that passes over laterally into marine beds, the thickness of the Catskill varies through a process of progressive off-lap. The feather edge of the Catskill is encountered in traversing west from Potter into McKean and Warren counties. A like pinching out to zero is observable in the Conemaugh gorge in southeastern Indiana County west of Johnstown, and similar conditions have been reported in Fayette County. From these lower limits the thickness rises to a maximum in the region between the Lehigh Valley and the Susquehanna. Claypole's 6,500 feet for Perry County's Catskill is excessive; 4,500 is nearer the truth; but the assigned thickness on the Lehigh as established by I. C. White (228) and Arthur Winslow (267) and rechecked by me must be nearly correct. There, from the base of the Pocono to the highest marine fauna is about 6,200 feet, but it may even be somewhat smaller, perhaps by 500 feet. From this we observe that the thickness of the Catskill in Pennsylvania reaches a maximum toward the southeast and thins away thence in a general northwesterly direction. This is emphasized by observing that in northeastern Pennsylvania the maximum is only a little over 2,500 feet as far as known. In north-central New Jersey the red beds are reported to reach a maximum of 2,500 feet, though it is only fair to say that the top is no doubt deeply eroded.

Limits.—The limits of the Catskill vary as radically as does its thickness. This might be expected from the nature, extent and other characteristics of the facies. The top is comparatively easy to define, but not so apparent in the field. This will be discussed further when the subdivisions of the facies are described. Still, it is pertinent to remark that, while the lower limit of the Catskill varies through a wide chronological range, the upper limit seems to be fairly synchronous throughout. This of course is to be attributed to a gradual off-lap of continental deposits which only ended, and then rather abruptly, with change to non-red Pocono sedimentation. The top is drawn simply where the red or green Catskill sandstones and shales yield place to the gray, usually conglomeratic Pocono. Much has been said, particularly by members of the Second Pennsylvania Geological Survey, on the subject of "transition beds" between the Catskill and Pocono. In a sense they were quite right; for among the non-red units of the Catskill, particularly those developed in the northeastern quadrant of the State, some beds so closely resemble the Pocono that confusion has been common. As such, they no doubt adumbrate Pocono conditions, but each unit may be shown to pass into marine strata with Devonian fossils. In areas where the non-red Catskill is not so well understood, this separation is difficult, and it must be frankly admitted that the line cannot always be sharply drawn. While it is estabilshed upon stratigraphic and paleobotanic evidence that the bulk of the Pocono from beyond the southern boundary of the State east at least to Mauch Chunk is of Mississippian age, there is still a possibility of a doubt as to the precise age of the lowest part of what many call Pocono. I have suggested that there is a confusion here of true Pocono with the somewhat similar "Oswayo" on the Allegheny Front. Nevertheless, for all practical purposes the top of the Catskill can usually be drawn with close approximation.

The base of the Catskill is quite another proposition. I shall soon discuss its age variations from east to west, so that the evidence for this need not be considered at present. Everywhere the line is vague, ragged. The continental beds inter-tongue with the marine, neritic facies of the Devonian which changes progressively from early Middle Devonian in New Jersey to Portage in the upper Delaware Valley, earliest Chemung in the Susquehanna Valley above Harrisburg, very late Chemung on the Allegheny Front and progressively later Chautauquan from north-central to northwestern Pennsylvania (See Figure 70).

THE CATSKILL OFF-LAP

In my paper " 'Catskill' sedimentation in Pennsylvania" published in 1933 (236), I described the off-lap of the Catskill continental facies from north-central New Jersey to Fayette County in the southwestern corner of Pennsylvania. Subsequently, I modified and amplified the contents of this paper in my description of the Portage group (245), and in remarks on the isolated exposures of Fayette and Indiana counties (237). A particular phase of it was presented in an article, "Early Chemung shore line in Pennsylvania" (239), a problem which will be reviewed in the next section of this chapter. The conditions in the northeast and north-central parts, while closely allied to the general problems of the Catskill, are so important that they too will be taken up separately.

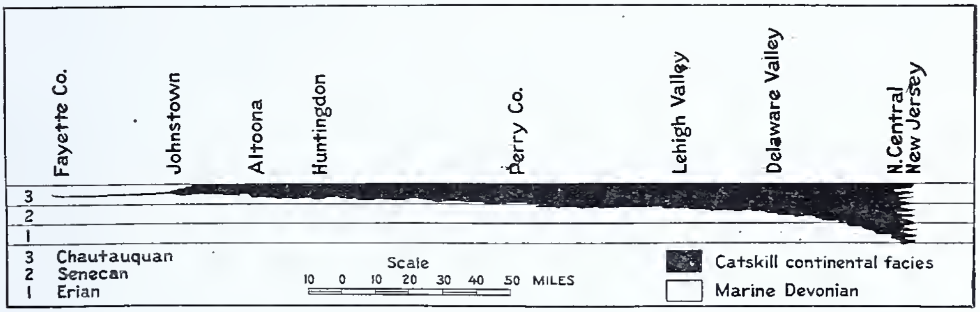


Figure 70. **Idealized section showing Catskill continental facies relations east and west across Pennsylvania.**

In my earlier article (236) on the Devonian continental off-lap I employed the nomenclature for subdivisions of the Catskill suggested by Chadwick. Since then, with the prosecution of studies in the northeast, these names have been repudiated. I shall review the subject, commencing in north-central New Jersey and working westward.

North-central New Jersey.—In north-central New Jersey in the Green Pond Mountain syncline, there is preserved a unique and remarkable band of Devonian isolated from all other known exposures of the system. The band extends into New York State, but my studies there have been too superficial to warrant the issuance of declarative pronouncements. The New Jersey portion I visited on three occasions, in all of which several days were spent in studying it. The sequence there, adapted from the publications of the New Jersey Geological Survey (223, 130, 140, 131, 132), runs:

Green Pond Mountain syncline, N. J.

Catskill continental facies
  Skunnemunk conglomerate
Marine Middle Devonian
  Hamilton group
    Bellvale sandstone
  Onondaga group
    Cornwall shale
    Kanouse sandstone and conglomerate

We are concerned with the Skunnemunk conglomerate, which is the local representative of the Catskill continental facies, and with the subjacent, marine Bellvale sandstone. Kümmel and Weller (130) placed a slightly different interpretation on this sandstone. From a study of its fauna Weller (223; p. 107) commented: "They are all Hamilton forms, with none of the characteristic Chemung species of the New York fauna". From the fact that the Bellvale overlies conformably beds which I believe are the clastic equivalent of the Onondaga limestone, from my own collection from the locality, from comparison with conditions observed in the Delaware Valley in Pennsylvania, and from analogy with the findings of Cooper in the Hudson and Schoharie valleys (79), I assign the Bellvale sandstone to the Marcellus. This was all pointed out recently in my paper, "Hamilton correlations" covering New York, New Jersey, Pennsylvania and Maryland (254). If the Bellvale is Marcellus (or at youngest early Skaneateles) then the conformably overlying Skunnemunk conglomerate shows definitely that Catskill sedimentation began here in late Marcellus or certainly not later than very early Skaneateles time. This determination is extremely important in view of what I shall explain to be the situation in eastern Pennsylvania.

The Green Pond Mountain region of New Jersey lies some 45 miles east-northeast of Stroudsburg and 25 miles east of the nearest Devonian outcrops in the Delaware Valley. It is a down-faulted syncline of Devonian and Silurian beds. Under the assumption that these New Jersey strata were once continuous with those of eastern and northeastern Pennsylvania, they are a valuable supplement. The Skunnemunk is a red to purplish conglomerate and sandstone succession which was looked upon by Barrell (12) as part of an ancient Devonian gravel plain separating the highlands to the east from a region of true delta forming to the west. Barrell understood its relations to the less coarse continental clastics of Pike and Monroe counties, Pennsylvania. The beds are practically barren, the only remains being a few plants from Orange County, New York, which Prosser (161) supposed to be post-Hamilton in age. From such data we may say that the very coarse Catskill of north-central New Jersey began to form in late Marcellus time and continued into the Upper Devonian. The top is clearly missing. Ries (169) recorded that the base cuts even lower near Cornwall, New York, where it reaches the Cornwall shale ("Pequanac" of early reports). This I have not verified. The Skunnemunk has not been subdivided in New Jersey. If, as Prosser supposed, it hardly reaches above the Portage, we should not expect to find much in the way of equivalents of the Catskill divisions of northeastern Pennsylvania, for these begin in relatively late Senecan time (Delaware River flags and Analomink red shale).

Delaware Valley.—Passing west from New Jersey into Pennsylvania, one again encounters the base of the continental facies along the west side of the Delaware Valley in Pike and Monroe counties. Sections are observable on the Delaware above Matamoras, and particularly valuable information was secured on Brodhead Creek near Analomink. The highest recognized marine fauna in this region is Portage (Ithaca) in age occurring in the Trimmers Rock sandstone, well developed northwest of the Delaware. It will be recalled that I. C. White (228) assigned these beds to the Chemung, an error erased by Prosser (161), whose correction I have verified. The Trimmers Rock sandstone is generally succeeded by a thin red member which I named the Analomink red shale (250). This in turn is overlain by the thick, greenish Delaware River flags of continental origin and so assigned to the Catskill, though their lithology suggests a continuation of Trimmers Rock conditions. They are actually on the border line, for Prosser (161) reported two marine fossils, "*Spirifer*" *mesacostalis* and *Leda diversa* from these flags in Brodhead Creek valley. Farther west they become fully marine, the Analomink goes out, and the Delaware River flags and Trimmers Rock sandstone coalesce. The Delaware River flags are succeeded by a more nearly normal Catskill type of red sedimentation in a thick series interspersed with non-red members. From these facts, the age of the basal Catskill (Analomink) in the Delaware Valley is approximately middle Portage or a trifle younger. The Delaware River flags appear to be the counterpart of at least the upper portion of the Oneonta formation of New York. Oneonta is a name in good standing and has been generally accepted, but it is not so useful here as Delaware River flags, the connotation of which name is apparent.

Lehigh Valley.—The next important section west is that on the Lehigh River below Mauch Chunk. Data have been drawn from both sides of the river and supplementary facts were taken in the region between the Lehigh and Brodhead Creek. I. C. White (228) and Arthur Winslow (267) recorded the Lehigh River section. Their annotations are in some respects excellent, but required revision when the Catskill below Mauch Chunk was restudied. There, the Delaware River flags have mingled with the Trimmers Rock sandstone with no Analomink red shale truly identified between them. Marine fossils in the now thickened Trimmers Rock (indistinguishable from the succeeding equivalent of the Delaware River flags) place its top in the upper Portage. The Catskill next above is dominated by red beds, but still carries some important non-red units, notably the Honesdale sandstone. At the Catskill-Portage contact some transitional beds are observable, colored olive, red and pinkish or plum. These suggest the Chadakoin of the northwest. In fact, as already mentioned, ''Chadakoin'' conditions seem likely to intrude wherever marine and fresh-water Devonian beds are transitional. Such beds are often nearly barren, but from Monroe County through Carbon and westward to the Susquehanna Valley, it is not uncommon to discover bands of *Tentaculites* and fragments of very small crinoid stems continuing above all other forms of marine animal life and suggesting that these may have been capable of withstanding brackish water conditions in an estuarine environment; or that they, being light and small, were swept by tide and current into shallow-water embayments. Evidently, then, the basal Catskill in the Lehigh Valley must be drawn rather high in the Portage, considerably above where I placed it in the Delaware Valley.

Section along the Lehigh River, in Carbon County, from Mauch Chunk to the Lehigh Water Gap by I. C. White (228)

Pocono Series, No. X.

1.	Conglomerate, very massive, grayish-white large pebbles	50′	750′
2.	Greenish-gray, sandy shales	50′	
3.	Conglomerate, dark gray, with coaly streaks, large pebbles	50′	
4.	Buffish-gray, sandy shales	120′	
5.	Dark buffish sandstone with some shales	430′	
6.	*Mt. Pleasant conglomerate*, base of *Pocono*	50′	

Catskill, (No. IX.)

7.	*Mt. Pleasant red shale*	red shale	40′	500′
		red sandstone	40′	
		red and green shales	60′	
		red conglomerate	10′	
		red shale	250′	
		red shale and sandstone	100′	
8.	Sandstone and shales, reddish			200′
9.	*Cherry Ridge conglomerate*	conglomerate	40′	200′
		greenish sandstone	110′	
		conglomerate	50′	
10.	Concealed			200′
11.	Gray pebbly conglomerate			60′
12.	Greenish flaggy sandstones			350′
13.	Grayish sandstones with two or three layers of red			175′
14.	*Calcareous breccia*			2′
15.	Massive, gray sandstone, interstratified with a few thin red beds.			120′
16.	*Red sandy shales*			30′
17.	Very massive, greenish-gray sandstone			120′
18.	*Red sandy shale*			60′
19.	Massive, greenish-gray sandstone beds with some pebbles			165′
20.	*Calcareous breccia*			8′
21.	Greenish-gray sandstone			180′
22.	*Calcareous breccia*			2′
23.	Greenish-gray sandstone			60′
24.	Variegated (green and red) beds			60′
25.	*Red sandy shale*			30′
26.	*Calcareous breccia*			2′
27.	Massive, reddish-gray sandstones, containing some quartz pebbles.			60′
28.	*Red shales and sandstone*			120′
29.	Gray sandstones wth very little red			150′
30.	Red and grayish-green sandstones			150′
31.	*Montrose red shale*, only a few thin streaks of gray in the whole interval			2000′

32. *Delaware flags*, no red beds whatever .... 1200′
33. A succession of gray sandstones, interstratified with *red shales* and *sandstones*, the *red beds* largely predominating.......... 700′
34. Greenish-gray flaggy sandstone in which occur occasional *red beds*, the lowest of the latter being 120′ above the base of the series, thickness ....about 600′

Chemung, (No. VIII)

35. A succession of bluish-gray and olive sandstones with some shale, sparingly fossiliferous .... 1200′

N. B. The above is quoted *ver batim* without change or annotation that it may be the better compared with modernized interpretation.

Mauch Chunk Section by A. Winslow (167)

For. No. XII, Pottsville conglomerate (thickness 1000′)

1.	Conglomerate and sandstone, silicious	820′	820′
2.	Shale, red	60′	880′
3.	Conglomerate, green with large quartz pebbles	120′	1000′

For. No. XI, Mauch Chunk red shale (thickness 2168′)

4.	Shales and sandstones, red	1662′	2662′
5.	Sandstone, yellow, friable	83′	2745′
6.	Shale, red	28′	2773′
7.	Sandstone, chocolate gray, hard	28′	2801′
8.	(Shales?) mostly concealed	367′	3168′

For. No. X, Pocono gray sandstone (thickness 1253′)

9.	Sandstones, gray, hard	25′	3193′
10.	(Sandstones, gray, with conglom.?)	309′	3502′
11.	Sandstone, gray, hard	46′	3548′
12.	Conglomerate with sandstone, medium, silicious	60′	3608′
13.	Shale and slate, dark	20′	3628′
14.	Sandstone, grayish, coarse	26′	3654′
15.	Slate, dark	13′	3667′
16.	Sandstone with pebbles, dark gray, silicious	50′	3717′
17.	Conglomerate, coarse silicious	14′	3731′
18.	Shale and sandstone, grayish green	28′	3759′
19.	Ochre, yellow	5′	3764′
20.	Shale, greenish	13′	3777′
21.	Ochre, yellow	5′	3782′
22.	Shales, olive green, ochery	55′	3837′
23.	Sandstone with shale, and slate dark gray	282′	4119′
24.	SS. white, fine, hard, (with soapstone layer at bottom)	48′	4167′
25.	Shales, dark. greenish and variegated	40′	4207′
26.	Sandstone, dark, gray and reddish; hard; (with few large, very widely scattered pebbles)	214′	4421′

For. No. IX, Catskill red SS., &c. (thickness 7145′).

27.	Sandstone, red, hard, with vitreous quartz grains	32′	4453′
28.	Shale, ochery	9′	4462′
29.	Sandstone, grayish green	27′	4489′
30.	Shale, red	18′	4507′
31.	Sandstone, shaly, light green, fine	5′	4512′
32.	Shale, red	9′	4521′
33.	Sandstone, red, hard	72′	4593′
34.	Sandstone, red, hard	30′	4624′
35.	Slates and shales, green	30′	4653′
36.	Shales and sandstone, red	49′	4702′
37.	Sandstone, greenish gray	19′	4721′

38.	Shale, red	202′	4923′
39.	Sandstone, green	10′	4933′
40.	Sandstone, red and greenish gray (with pebbles)	49′	4982′
41.	Shale, red	19′	5001′
42.	Sandstone, chocolate gray (with quartz pebbles)	44′	5045′
43.	Sandstone and shale, red	70′	5115′
44.	Sandstone, reddish brown, hard, coarse (with quartz pebbles, scattered, and in bands)	147′	5262′
45.	Shale, greenish gray (with scattered pebbles)	106′	5368′
46.	Sandstone, conglomeratic, chocolate red (with quartz pebbles)	12′	5380′
47.	Sandstone, greenish gray, hard, flaggy, (with quartz pebbles, scattered and in thin bands)	516′	5896′
48.	Sandstone, red	11′	5907′
49.	Flaggy sandstone like 47	547′	6454′
50.	Sandstone, greenish gray, fine, with shale	526′	6980′
51.	Sandstone, red, shaly	47′	7027′
52.	Sandstone and shale, greenish	160′	7187′
53.	Sandstone and shale, reddish	37′	7224′
54.	Sandstone, grayish green	113′	7337′
55.	Shale, red	57′	7394′
56.	Sandstone, greenish gray, silicious	225′	7619′
57.	Shale, red	19′	7638′
58.	Sandstone and shale, greenish	111′	7749′
59.	Sandstone and shale, reddish	37′	7786′
60.	Sandstone and shale, greenish	19′	7805′
61.	Sandstone and shale, red, (with *calcareous band*)	56′	7861′
62.	Sandstone, greenish gray	37′	7898′
63.	Shale, red	92′	7990′
64.	Sandstone, greenish gray	139′	8129′
65.	Sandstone and shale, red	19′	8148′
66.	Shale, green	37′	8185′
67.	Shale, red	92′	8277′
68.	Sandstone, green	46′	8323′
69.	Shale, red	307′	8630′
70.	Shales, red and green, variegated	84′	8714′
71.	Shales, red	310′	9024′
72.	Sandstone and shale, greenish gray	20′	9044′
73.	Shales, red	105′	9149′
74.	Shales, green	15′	9164′
75.	Shales, red	25′	9189′
76.	Shales, green	20′	9209′
77.	Shales, red	60′	9269′
78.	Shales, grayish green	42′	9311′
79.	Shale, red with thin green bands	548′	9859′
80.	Sandstone, greenish gray	110′	9969′
81.	Sandstones, red	6′	9975′
82.	Sandstones, greenish gray	15′	9990′
83.	Sandstone, red	5′	9995′
84.	Sandstones, greenish gray	1155′	11150′
85.	Shales, red and green	104′	11254′
86.	Shales, red (some green)	312′	11566′

For. No. VIII, g, f, Chemung and Portage (thickness 1292′).

87.	Shales and slate, dark and hard, flaggy sandstone	700′	12266′
88.	Shales, dark, fissile, with little sandstone	592′	12858′

For. No. VIII, e, Genesee shales.

89.	Shales, black, fissile, much broken, (visible)	290′	13148′

N. B. The above is quoted *ver batim* without change or annotation that it may be the better compared with modernized interpretations.

Susquehanna Valley.—From the Lehigh to the Susquehanna and Juniata valleys, particularly in eastern Perry County, is a jump of some 60 miles. Data on the Catskill may be obtained at several intermediate localities, notable along the Schuylkill River and in the valley of Swatara Creek. These intermediate sections bear a close similarity to that on the Lehigh in that the lowest Catskill comes in as a transitional band above beds of late Portage age. The age change of the basal Catskill from the Lehigh nearly to the Susquehanna is, therefore, relatively slight.

Mention here may conveniently be made of the relations near the forks of the Susquehanna. As determined by Williams and Kindle (265) and reaffirmed by me (232), the basal Catskill near Selinsgrove Junction (Hallowing Run section) and eastward in the section near Catawissa is of late Portage age. But farther east, on Wapwallopen Creek in Luzerne County, I found a trace of Chemung below the red beds.

The Susquehanna-Juniata valleys region, primarily Perry County, illustrates a decided change in age of the basal Catskill in a direct line west from the Lehigh. Here, on the Juniata above Amity Hall, the beds immediately beneath the lowest truly red Catskill are assigned, though without absolute certainty, to the Parkhead. This, it will be recalled, is the division of the Upper Devonian immediately preceding the Chemung in Maryland. The beds are quite fossiliferous, and have a chocolate color very unlike the older subjacent Trimmers Rock sandstone and distinct from the overlying red beds. In this color they are reminiscent of the Chadakoin. Were color the only evidence I would call the basal Catskill in this region the equal of the Parkhead (?) or youngest Maryland Portage, but other data are on hand. On the Susquehanna near Half Falls Mountain and across the river in Dauphin County, *"Spirifer" disjunctus* has been found in a few feet of gray to brownish beds between the Catskill and strata of Portage age. The basal red beds have risen to very early Chemung age here as in southeastern Luzerne County. We shall see presently that recurrent Chemung faunules are known from the lower part of the Catskill in the Juniata Valley in Perry County, but their importance is the light which they throw upon the age of this *lower part* of the Catskill, rather than its *base*.

Allegheny Front.—Comparatively little need be said of the age of the basal Catskill from Perry County west or northwest to the Allegheny Front. It is nearly 90 miles to Altoona. In western Juniata County, the red beds begin in later Portage time. This apparent regression from the Chemung of Perry County will be explained in the next section on shore line development and its irregularities in Chemung time. On the Juniata in the vicinity of Huntingdon there is a considerable thickness of Chemung between the Portage and Catskill, but the exact number of feet has not been ascertained. A wedge of Chemung has been observed south of the Broad Top field. Along the Allegheny Front the lower Chatauquan has thickened greatly so that the red beds commence in quite late Chemung time. At Lock Haven, beds of Wellsburg age are known beneath the Catskill facies development. Near Altoona, in the rightly famous Horse Shoe Curve section on the Pennsylvania Railroad, the age of the basal red beds is also probably Wellsburg.

Southwestern Pennsylvania.—West of Johnstown the Conemaugh River gorge through Laurel Hill anticline cuts down into marine Upper Devonian strata. A nearly uninterrupted section completely across the arch lays bare the rocks, from the Coal Measures down, on both limbs of the fold. On the east flank, characteristic Catskill red sandstone and shales underlie the Pocono. On the west flank the Pocono overlies marine Devonian beds without intervening red strata. It is probable that these beds are very late Chemung, but there is a chance that they are younger. The fauna is meager and poorly preserved, and at best is only generally diagnostic. This locality is 25 miles west of the Horse Shoe Curve section.

At Ohiopyle in northeastern Fayette County, marine Devonian and Catskill continental beds are exposed along the Youghiogheny River, but the few poorly preserved fossils collected were inadequate as evidence of the precise age of these beds, although they are perhaps not younger than latest Chemung. On Chestnut Ridge, east of Uniontown, Fayette County, and to the north where the Youghiogheny River transects this anticlinal ridge, near the mouth of Indian Creek, the Pocono overlies marine Upper Devonian beds without trace of red material between. The already mentioned faunas are puzzling. The fossils on Chestnut Ridge are probably of late Chemung age, but may be younger. At all events, there is no Catskill here, showing that the transgresssion of the continental beds did not reach this point during the closing stages of the Devonian, unless they were subsequently done away with during the Devonian-Mississippian hiatus. I say "closing stages of the Devonian" because of reported red beds at some depth in well borings in Fayette County. Considering the irregular nature of the western limit of the Catskill and the vacillating conditions under which it was laid down, temporary advances and retreats may be expected.

Summing up the data anent the age of the base of the Catskill, we observe that, except for local fluctuations, there was a continued, progressive transgression of the red beds or a non-marine off-lap from north-central New Jersey to Fayette County. That the actual outbuilding was in a northwesterly direction is not questioned, but my sections were taken in such places that it has necessitated the discussion of the off-lap being confined to a nearly east-west line. I conclude that:

1. As followed westward, the base of the Catskill rises progressively. There are small variations, apparent local regressions, but generally there is a progressive, and, on the whole, steady westward rise to the highest known red beds on the southwest at Johnstown.

2. Nowhere in these sections does the base of the red beds definitely rise as high as in the north-central and northwestern counties. This is significant, in view of the progressive northwestward thinning of the Catskill, as it points to an off-lap in a more northwesterly than westerly direction. The northwestward off-lap may be demonstrated.

Not only is there a progressive thinning from southern Carbon to Wyoming County, but the basal Catskill is progressively younger in that direction. I have only to repeat that the age of the base of the continental facies south of the Anthracite Fields on the Lehigh is fairly late Portage, and that in Luzerne County northwest of these fields it is early Chemung. It is still younger in our north-central counties. Tabulating, east to west, we have:

Table XXIX, The Descent of the Red Beds

Location	West—East									Northwest—Southeast			
	Fayette County	Johnstown	Altoona	Huntingdon	Perry County	Lehigh Valley	Brodhead Creek	U. Delaware Val.	North-cen. N. J.	McKean County	Tioga County	Luzerne County	Carbon County
Post-Chemung	x?									x	x		
Chemung		x	x	x								x	
Parkhead (?)					x								
Upper Portage						x							
Middle Portage							x	x					x
Lower Portage													
Hamilton													
Marcellus									x				

This realization of the direction of off-lap is important because of the tendency, particularly among New York stratigraphers, to assume an east-west off-lap. This definitely is not the truth in Pennsylvania. The western shore of Appalachia, at least in New Jersey, Pennsylvania and Maryland, trended northeast-southwest, not north-south. It had irregularities, as we shall presently see, but such was its trend; and the continental beds tended to build in a direction generally at a right angle to the coast, that is, northwestward. In the chapter on the Hamilton, I mentioned the occurrence of red beds (Knobsville member) of that age in Fulton County. These alone, coupled with the conditions in New Jersey, clearly indicate the trend of the shore line. If the hidden Upper Devonian beds across western Pennsylvania between Tioga, Erie and Fayette counties could be observed, we should doubtless find the basal Catskill rising toward Erie, that is, on a line roughly normal to the coast. It is hoped that, some day, deep-drilling will prove or disprove this thesis.

EARLY CHEMUNG SHORE LINE IN PENNSYLVANIA

It is nearly a quarter of a century since Joseph Barrell (12) published his classic account of the Upper Devonian delta of the Appalachian geosyncline. In it he dwelt upon Catskill conditions in eastern Pennsylvania. In the twenty-odd years since he wrote, new data have accumulated which affect somewhat the correlations and change some of the less important details, but at the same time fortify the original thesis. As a continuation of the basic facts of the problem which Barrell presented, I attempted a few years ago to trace the early Chemung shore line across Pennsylvania (239). The results of this work were published in 1934, and will be here repeated with very slight changes, since nothing particularly new has been found to modify these observations.

The progressive off-lap of the Catskill continental facies during latter Devonian times in Pennsylvania has been set down in the preceding section of the present chapter. I have traced the age of the base of the Catskill from north-central New Jersey westward to southwestern Pennsylvania. We have seen how the Catskill facies commenced to form in Marcellus time in the east and continued until Chemung time at least in the southwest. I shall presently indicate that it transgressed Chemung in the northwest. Data additional to those already given enable one to trace the early Chemung shore line across Pennsylvania from New York to Maryland.

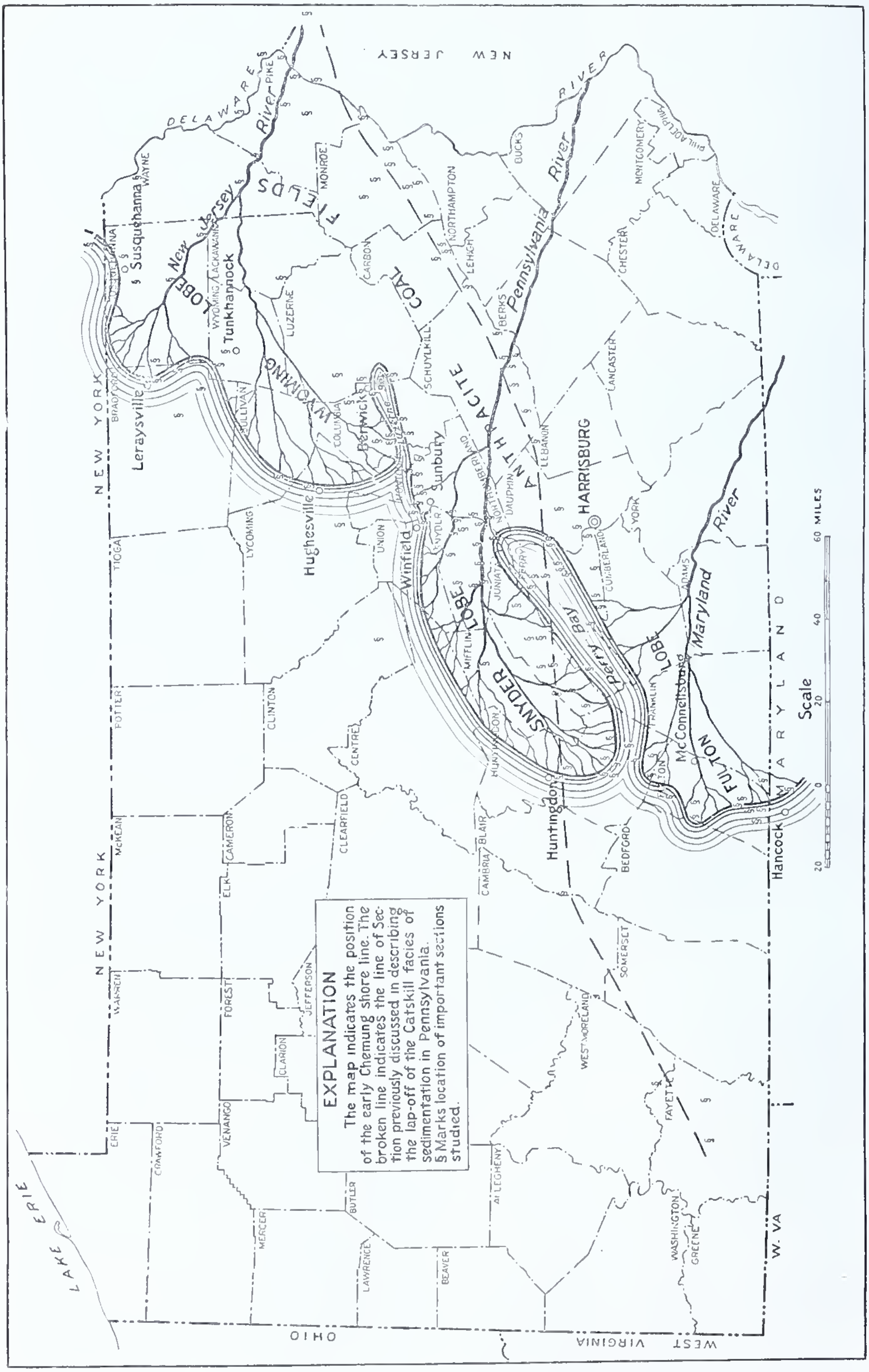
The Chemung group lends itself particularly well to this problem of shore line delineation because at the time of its earliest deposition, progressive, non-marine off-lap had reached well into central Pennsylvania, so that the eastern limit of Cayuta (lower Chemung) sedimentation completely traverses the State. Furthermore, while older groups of the Devonian, (Hamilton and Portage) pass beneath the post-Devonian formations of the Anthracite Fields in eastern Pennsylvania, and so cannot be completely studied everywhere in their eastern regions of preservation, the eastern limits of the Chemung are exposed abundantly to the northwest and west of the Anthracite Fields and thence southward to Maryland. Except for minor concealments, the lower part of the Chemung is nowhere entirely hidden, although it has been eroded in some places. This discussion is introduced here rather than in the chapter embracing the Chemung, since it is actually more closely tied in with the behavior of the Catskill continental off-lap than with the character of the Chemung group itself.

Establishment of the Shore Line

In studying the Middle and Upper Devonian of Pennsylvania, I made a particular point to follow the several salt-water groups or formations eastward and southeastward to that point where their last remnant has either been eroded entirely or their identities lost through shoreward transition into fresh-water, red or green beds. Those marine formations whose eastern limits are found beyond Pennsylvania's eastern edge, have been studied in New York, New Jersey and Maryland. The necessity of this has been seen in the case of the Hamilton. The Portage group behaves in like manner. Non-marine sediments displace successively older beds of the group from the Susquehanna River east to the Delaware Valley. In Fulton County, as noted in the Hamilton descriptions, red beds locally displace nearly the entire Hamilton and continue into the Portage and Chemung. Non-marine Portage occurs from the Susquehanna Valley east, but from Perry County west there is little continental Portage. The Chemung in turn passes over into non-marine beds in the general region of the Susquehanna Valley and the North Branch thereof. Such data as these demonstrate continental off-lap from the east and southeast beginning in early Middle Devonian time and continuing progressively to Chemung or later at the Allegheny Front.

Chemung rocks form the surface exposures or underlie approximately the entire western two-thirds of Pennsylvania and extend eastward from the Allegheny Front as far as the Susquehanna Valley and thence into the northeastern corner of the State. Studies of the Upper Devonian fossils and stratigraphy have determined the eastern limit of the Chemung. The first appearance of *"Spirifer" disjunctus* everywhere marks the bottom of the Chemung. All of these "first occurrences" of this brachiopod are assumed to be essentially synchronous. For our purpose this no doubt is true, although from an ecologic standpoint it is not so precise. Non-marine off-lap in early Chemung time appears to have been fairly rapid. The eastern limit of marine Chemung also is determined by the use of *"Spirifer" disjunctus.* Just as this fossil marks the base of the group, so it may be used to point out the easternmost extension of the same beds, especially where they are the youngest marine Devonian present. Therefore, wherever the lower and eastern limits of distribution of *"Spirifer" disjunctus* are recognized and roughly coincide, a point is established marking the position of the coast at that time. By obtaining and connecting several such points which represent the easternmost extension of the marine beds in early Chemung time, the trace of the contemporaneous shore line may be drawn.

The Chemung shore line crossed Pennsylvania in a southwesterly direction from Susquehanna County not far from Susquehanna village near the northeastern corner of the State to Fulton County on our south-central border. The line is irregular. Three deltas or delta lobes are recognized, separated by two embayments. Upon crossing from New York State into Susquehanna County, the shore line turns immediately west to east-central Bradford County (near Leraysville), where it swings southeast rather sharply into northwestern Wyoming County, makes a small embayment north of Tunkhannock and passes southwestward into Sullivan County. In this place is one of the few completely concealed parts of the Chemung, caused by the presence of overlying Carboniferous formations, but the trace presumably doubles back southeastward once more in a broad loop terminating near Hughesville. The basal Chemung once more appears in southwestern Luzerne County near the Susquehanna River opposite Berwick. This first protuberance of the coast line in northeastern Pennsylvania has been named the *Wyoming delta lobe* from Wyoming County near its center. The reëntrant near Berwick has been named *Luzerne Bay,* from Luzerne County. These features are all depicted in Figure 71.



EXPLANATION

The map indicates the position of the early Chemung shore line. The broken line indicates the line of Section previously discussed in describing the lap-off of the Catskill facies of sedimentation in Pennsylvania.
§ Marks location of important sections studied.

Figure 71. **Sketch map to illustrate hypothetic position of the early Chemung shoreline in Pennsylvania.**

Continuing down the coast, the shore line next turns westward along the southern boundary of Luzerne Bay to cross Columbia, Montour and Northumberland counties and continue westward, southwestward and southward. The coast has a small indentation in southeastern Union County, south of Winfield, but in other respects is reasonably straight along the northern edge of a large peninsula, referred to as the *Snyder delta lobe,* from Snyder County at its base. The northwestern limit of this lobe could not be as nicely delineated as most other parts of the shore line because erosion has taken off much of the Devonian, chiefly the Upper Devonian, in the closely folded area of central Pennsylvania. Nevertheless, the trace has been carried on to accord with inferences from data projected eastward from the Allegheny Front as a supplement to such occurrences of the Chemung as are preserved to the east. The outline of the Snyder lobe is so drawn as probably closely to approximate the truth. The southern border of this lobe is a very problematic feature and caused considerable speculation. In southeastern Huntingdon County, the coast was determined easily and in central and southern Fulton County, but no uppermost marine Devonian occurs between the respective areas. Probably a narrow strait extended eastward from the region of southeastern Huntingdon County, because *"Spirifer" disjunctus* is rather common in northeastern and eastern Perry County and the extreme west-central part of Dauphin. The fauna seems not to have reached this point via any southern passage, for pre-Chemung continental beds block the way in southeastern Perry County. The character of the eastern Devonian in Maryland supports this inference. At the same time the Snyder lobe prevented the entrance of Chemung invertebrates from the north, and continental conditions were already dominant throughout the east. Careful lithologic comparison and studies of many sections in detail in northern Fulton and adjacent parts of Huntingdon and Juniata counties have finally delimited *Perry Bay,* named from Perry County, along the south side of the Snyder lobe.

The *Fulton delta lobe,* which is named from Fulton County, lies south of Perry Bay and reaches into Maryland. This lobe is the least sharply defined of all. If the Maryland portion were carefully studied, we should be able more clearly to draw its limits. Reliance had to be placed upon published reports dealing with the geology of Maryland, supplemented by all-too-brief trips south of the Mason-Dixon line.

Origin of the Shore Line Features

Source of delta sediments... The foregoing tracing of the irregular, early Chemung coast over an airline distance of slightly more than 200 miles shows three deltas separated by two embayments. When the study was begun, it appeared as if a single large delta approximating in size that of the present Mississippi River had existed, but further refinement of work showed it to be broken up into three which I have postulated to have been laid down by as many relatively short rivers, each supplying sediment to a respective delta lobe. Several lines of evidence support such a theory. The highlands of Appalachia were located by Barrell approximately coincident with the present "fall line", a view with which my observations on continental off-lap concur. The character of the Upper Devonian marine beds in particular and, to a less extent, those of the Middle Devonian agrees with this view. A rapid accumulation and deposition in rather strong currents of large amounts of relatively coarse material is observed. The shifting currents deposited coarse, often cross-bedded sands with occasional pebble beds such as make up the fresh-water components of the Devonian. The salt water beds are similar in many respects save for colors and organic remains. Off-lap progressed strongly throughout the late Devonian, and the bays tended to fill rapidly. The narrow strait opening from Perry Bay toward the western interior sea closed in early Chemung time, and the eastern end of the bay was thereafter landlocked until it eventually filled in. This separation is inferred from the dwarfed and specifically restricted nature of the fauna which succeeds the first appearance of "*Spirifer*" *disjunctus* in eastern Perry County.

The three hypothetical rivers which supplied the sediments to the three delta lobes are indicated on the map (Figure 71), although to be sure their courses are largely conjectural. In the north is located the *New Jersey River*. Rising in or near northern New Jersey, this stream ran northwestward across northeastern Pennsylvania and built out the Wyoming lobe. Two subsidiary lobes along the outer margin of this main lobe are attributed to distributaries of the New Jersey River. In the south, the *Maryland River* is presumed to have risen somewhere in northeastern Maryland and distributed its load northwestward into the sea. Small irregularities of coast line imply that, like the New Jersey River, the Maryland River broke up into distributaries across its delta. Between these two streams, a third, designated the *Pennsylvania River*, is thought to have had its source in central New Jersey, thence it crossed eastern Pennsylvania in a northwesterly direction, and debouched in the area south and west of the present forks of the Susquehanna River near Sunbury. Its chief work was the building of the large, kidney-shaped Snyder lobe. With the coalescence of the Snyder and Fulton deltas, Perry Bay was cut off from the sea. Like conditions may eventually have obtained in the head of Luzerne Bay, but conclusive data on such are unknown because so much of the Devonian has been worn away from parts of Northumberland and Union counties. By late Chemung time the features recognized at the opening of the Chautauquan seem largely to have disappeared with the continued off-lap of the Catskill magnafacies and the progressive migration of the shore northwestward.

While the general boundaries of the three deltas and their intervening embayments are thus established with reasonable certainty, the component parts of the deltas are not readily recognized in every case, even following a study of the minutia of the stratigraphy. Generally, the succession of sediments met in passing upward in any one section shows an increase in coarseness from marine to fresh-water strata. Simultaneously, the strata lose their regular, marine bedding.

Cross-bedded strata gradually become more and more common until, with the disappearance of sea-dwelling animals, or even before they are totally lacking, cross-bedded, coarse, often greenish sandstones are common in many sections. These, in turn, alternate with red sandstones and shales; and "Chadakoin" coloration may show until purely continental conditions dominate. I have spoken of this transition in several sections and how marine remains may be found in beds which are lithologically intermediate between characteristic marine strata and continental beds. Above the truly salt-water beds, the sediments of the three lobes differ only slightly. As these parts of the lobes are doubtless of contemporaneous origin and presumably derived from similar terranes, the resemblance is not surprising. It is hoped that eventually an adequate petrographic study of the minerals of the pebble beds of the continental sediments and of their sand grains may be made with a view to a more precise determination of their sources.

Deflection of the Lobes

The axes of the lobes have a curious twist toward the southwest. Such turning suggests a long-shore current flowing in the direction of deflection. The supposition is that Pennsylvania's part of the Appalachian coast, in early Chemung time, bordered a large embayment of the late Devonian epeiric sea, which embayment reached into western New York, down into Pennsylvania and beyond. The deflection of the lobes suggests a clockwise rotation of the waters of the sea and expresses a resultant between river currents and oceanic circulation.

Sedimentary history. It is unnecessary to go into minute discussion of each of the three lobes. Instead, I shall take up the characters of the Snyder lobe, which is the largest and best understood of all three. From this area the sea of Chemung times was excluded by the advance of continental sediments which had already encroached during the Portage. Irregularities of sedimentation began early in the Devonian in the region of its eastern half. I have elsewhere pointed out certain anomalies of sedimentation in the region of the Susquehanna Valley, particularly as regards the Onondaga and succeeding Middle Devonian beds. The Oriskany and Helderberg, and the Portage may be suspected of not being entirely orthodox. The region appears to have been unstable, and it is not improbable that some sort of barrier may have developed here early in Devonian times if not continuing back into the preceding period. The coarse sandstones in the Marcellus and later Hamilton beds are notable in this respect. They may represent the former position of the Maryland River, its predecessor or a distributary. The source of these sand appears to have been toward the south. The Middle Devonian sediments here are nearly all marine, but in Portage time, among the gray to greenish, more or less cross-bedded, flaggy Trimmers Rock sandstone one is led to suspect, that, while this sandstone is doubtless largely or wholly marine, some of it may have formed rather near shore. Such is substantiated by the theory advanced relative to local ice in Portage time. The Trimmers Rock too closely resembles the

Delaware River flags of the east to escape suspicion. North and west it becomes more normal Portage sediment. From these circumstances I assume that conditions leading up to the forming of the Snyder lobe (and the other two as well) began actually to make their presence felt long before continental sediments were deposited in any appreciable amount.

The source of the sediments is a theme worthy of speculation, though devoid of very substantial proof. The axis of the Snyder lobe, for example, tends slightly south of east, curving southwestward in the more remote part. The younger beds, presumably, were influenced more and more by the prevailing marine circulation. If the axis be projected southeastward, it is seen to pass through or near the southern border of the Southern Anthracite Field. It is pertinent here to repeat that in this region, from the Susquehanna to the Lehigh, are probably the thickest Devonian sections in Pennsylvania. The thickening being somewhat greater to the east than west, the condition is not strictly in accord with the findings of the Second Survey. If these facts of lithology and thickness be true, they define rather closely the direction from which the material for the Snyder lobe came and the probable course of our hypothetical Pennsylvania River.

In conclusion, I find that the early Chemung shore is traceable from northeastern to south-central Pennsylvania. Along it are recognized three delta lobes separated by two embayments. The lobes tend to swerve southwestward, a deflection attributed to currents skirting the shore of an embayment of the epeiric sea of Devonian North America. The lobes are thought to have been each produced by a river from the highlands of Appalachia to the east. Delta construction began in pre-Chemung time, if irregularities in sedimentation in Lower and Middle Devonian formations may be trusted as a key to the situation. In general these results agree with Barrell's original thesis on the position, origin and extent of the Upper Devonian delta of the Appalachian geosyncline in so far as Pennsylvania is envolved. The present discussion is a development of details which were not included in earlier studies of the region.

CONTINENTAL UPPER DEVONIAN OF NORTHEASTERN PENNSYLVANIA

In 1931 the Pennsylvania Topographic and Geologic Survey published a geologic map of the State, which, while an improvement over the previous ones of 1858 and 1893, unwittingly embodied certain errors which had been made in the older maps. In 1936 (250) I called attention to inaccuracies affecting the Devonian stratigraphy of northeastern Pennsylvania, and showed in what way they might be corrected. We are now concerned principally with the stratigraphy of the surface rocks of Susquehanna, Wayne, Pike, Monroe and parts of Bradford, Wyoming, Lackawanna, Luzerne and Carbon counties and to a lesser extent with other counties, primarily those forming our northern tier and those of the Susquehanna-Juniata valleys region. Additional facts are recorded for that part of the State lying

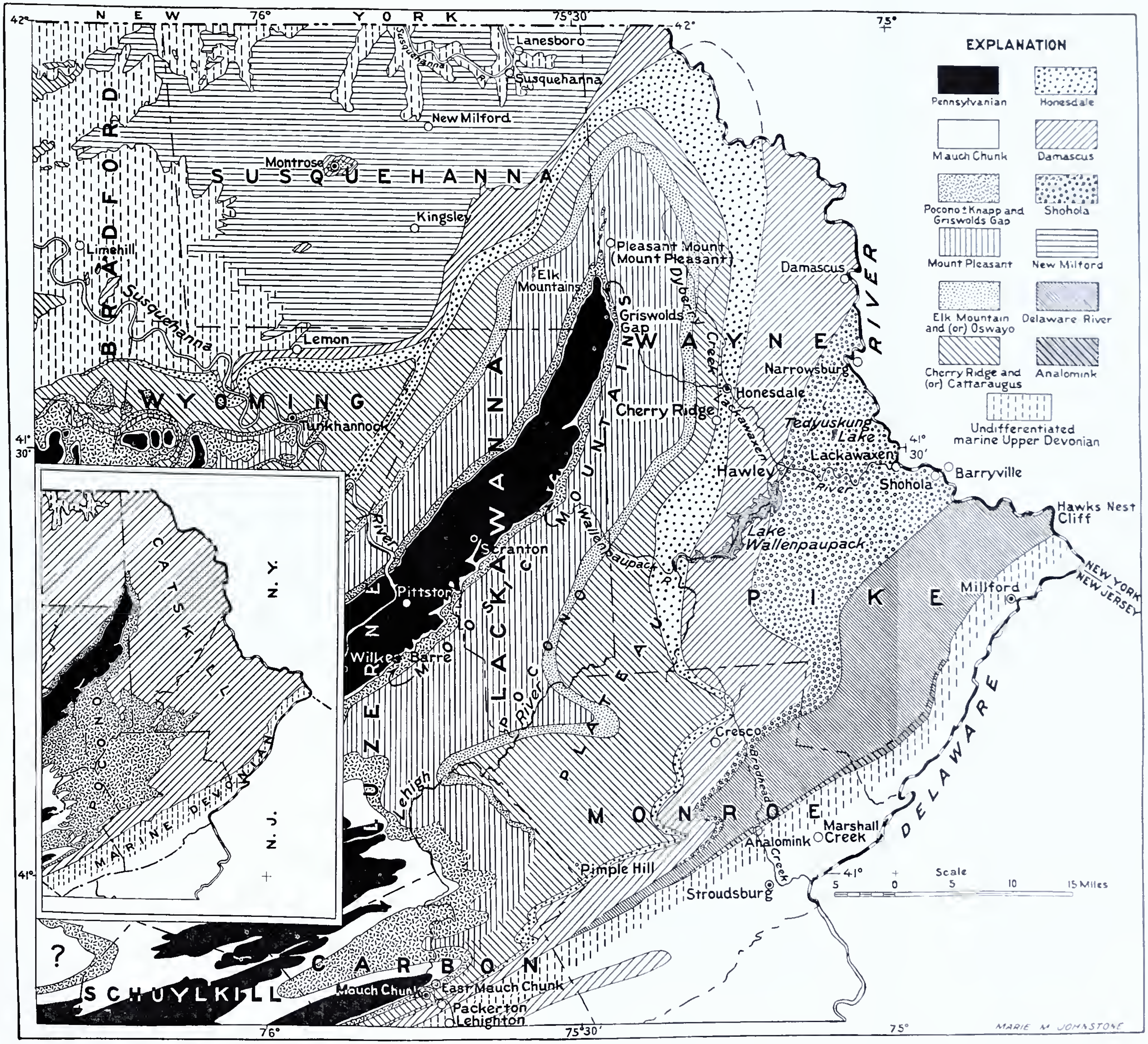
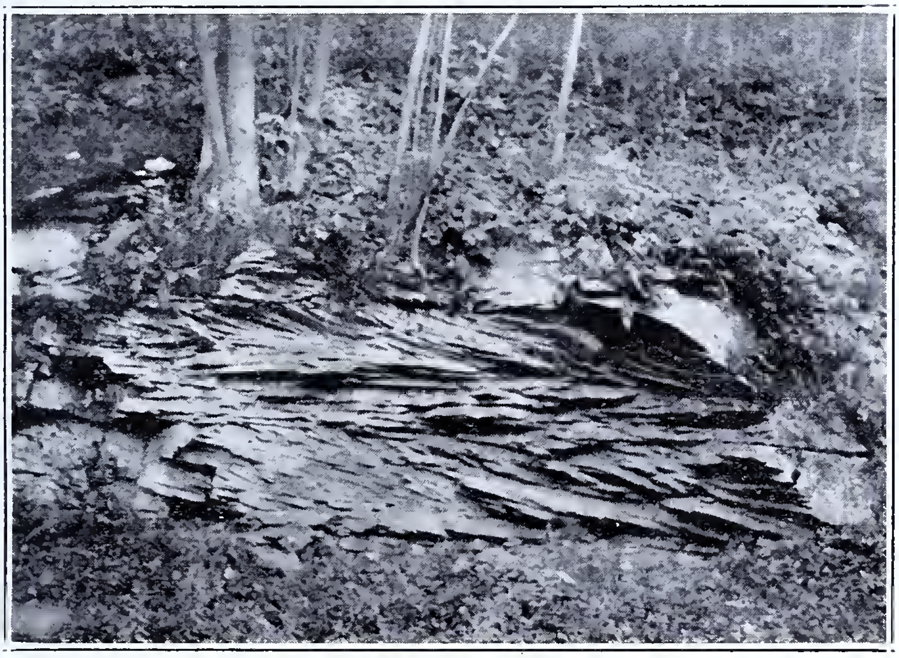


Figure 72. Geologic map (generalized) of northeastern Pennsylvania to indicate the distribution of the various units which there comprise the Catskill facies.

north and northwest of the Allegheny Front. It has been necessary to include references to the Mississippian, partly because of its close relations to the Devonian and partly because there is a certain tendency to confuse, as does the State map, the Mississippian and Devonian continental beds in the northeast. This discussion is based primarily upon my own field work. The thoroughness of this has not been uniform, for attention to the Catskill was concentrated on the northeastern quadrant of the State. Numerous sections have been studied and measured, but glacial drift is heavy in the northeast so that actual tracing is often out of the question. However, the sections studied are so numerous and so near together that it is felt a close approximation to the truth has been attained.



Photograph by Bradford Willard

Figure 73. **Example of cross-bedded greenish sandstone at top of Catskill on the Allegheny Front, Bedford County. This is the type of stratification common in the sandy Oswayo, Elk Mountain, and, to a lesser degree, Honesdale.**

The region to which greatest attention will now be devoted lies in the Allegheny Plateau, and embraces also the Pocono Plateau. The Allegheny Front also enters the discussion, as do the anthracite basins and the folded "valleymont" portion of the Appalachian Valley. Throughout, it may be taken as axiomatic that the higher areas are underlain by Mississippian and Pennsylvania formations, the lower by Devonian strata. The post-Devonian beds usually occupy gentle synclines, but the Devonian formations come to the surface along low anticlines.

Distribution and Sequences

We have already seen that the Devonian occupies a large part of the surface of Pennsylvania and that the continental facies is dominant. With the Mississippian, the Devonian surrounds the coal fields and spreads wide in the intervening areas. The continental Devonian is the principal surface rock of the northeastern quarter of the State. On the 1931 and all previous State geologic maps, a considerable area of the Mississippian is shown in the northeast under the name of "Pocono". My studies reveal that this so-called "Pocono" is chiefly Devonian mistakenly identified. This applies to most of the Pocono Plateau proper and the northern part of the Allegheny Plateau likewise. Mississippian beds are present, nevertheless, as a fringe about the Anthracite Fields, along the Allegheny Front, in certain of the ridges in the central part of the State and in the western half of Pennsylvania. The limits are usually somewhat more restricted than would be inferred from the State maps (Figure 72).

The continental Devonian strata exposed so widely in our northeast continue thence about the Anthracite Fields and reach out in bands into the central part of the State and along the Allegheny Front and penetrate the northern tier of counties. Isolated patches of Catskill are also known southeast of the Front.

Generalized marine sequence. The sequence of Pennsylvania's highest marine Devonian as typified in the northwestern sections and has been cited in Chapter VII. For convenience, it is summarized as follows:

- MISSISSIPPIAN SYSTEM (lowest part)
  - Knapp conglomerate
  - Kushequa shale*
- DEVONIAN SYSTEM (upper part)
  - Conewango group
    - Oswayo shale (partly non-marine)
    - Roystone coquinite
    - Cattaraugus red shale (mostly non-marine)
    - Panama conglomerate
  - Conneaut group
    - Chadakoin shale ("stage" of Caster)
    - Girard shale
    - Cuba sandstone
  - Canadaway group
  - Chemung group

Sequences in northeastern Pennsylvania. The Devonian and Mississippian continental sequences in northeastern Pennsylvania down to and including the highest marine are given in the following summary table based upon the successions in Susquehanna, Wayne and Pike counties. In the two columns are given the order of formations on opposite sides of the Lackawanna syncline (Northern Anthracite Field). In each column the sequence is carried down to include the highest marine beds exposed:

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* Fettke has taken issue with Caster on this section, claiming that at Kushequa the "Knapp conglomerate" includes practically all of the so-called "Kushequa shale," and that the bed here named "Flat-iron" (Roystone) coquinite is the same as the Marvin Creek limestone of Ashburner (see 94, pp. 26-33) (G. H. A.).

TABLE XXX, CONTINENTAL DEVONIAN IN THE NORTHEAST

Susquehanna County	**Wayne and Pike Counties**
MISSISSIPPIAN SYSTEM (lower part)	
Pocono formation	Pocono formation
Griswolds Gap conglomerate	Griswolds Gap conglomerate
DEVONIAN SYSTEM (upper part)	
CATSKILL FACIES	CATSKILL FACIES
Mt. Pleasant red shale	Mt. Pleasant red shale
Elk Mountain sandstone	Elk Mountain sandstone
Cherry Ridge red beds Dyberry glomerate	Cherry Ridge red beds Dyberry glomerate Pimple Hill conglomerate
Honesdale sandstone	Honesdale sandstone
Damascus red shale	Damascus red shale
CHEMUNG GROUP (in part)	
New Milford formation* Luthers Mills coquinite* Lanesboro member* Kingsley red shale Cayuta formation*	Shohola formation Paupack sandstone Barryville member
PORTAGE GROUP* (Concealed)	Delaware River flags Analomink red shale *PORTAGE GROUP* Trimmers Rock sandstone*

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* Units partly or wholly marine. Uppermost New Milford beds are post-Chemung; in the east, they are continental and assigned to the Catskill facies; in the west, they carry the marine Luthers Mills coquinite. Remainder of New Milford is probably Wellsburg in age and is partly continental, partly marine. Barryville member is Chemung in age, but Paupack sandstone is wholly or partly post-Chemung and equal in part or all to the New Milford. Delaware River flags and Analomink red shale are of Portage age, but belong with the Catskill continental facies.

Purposely, a rather loose nomenclature is here employed because of the probability that changes in correlations and designations of the various units are almost certain to arise with time and future studies by later investigators in the field. In general, I have been able to divide the Catskill continental facies or magnafacies into several parts, some of which probably are truly "parvafacies", to quote Caster's term. All the divisions mentioned in the table are separable on lithologic grounds and are usually readily mappable. The succession is essentially that established and expounded by I. C. White in his reports for the Second Survey which appeared in the 1880's (226, etc.). The quality of his work in this respect deserves particular mention. Working under handicaps of inadequate maps, in a series of beds almost devoid of recognizable fossils, White did excellent work. Unfortunately, Lesley (in White, 228) failed to appreciate some of White's observations and subsequent deductions; or, it may be that he felt that his own work of forty years before was better and should serve as a basis for interpreting the northeast. At any rate, White's work was restricted. White's conclusions must have been correct, but Lesley's editorial dictatorship altered the published accounts. I accept White's interpretations, with relatively slight emendations, as they appeared in volumes G5, G6 and G7. Some of his subdivisions are too local to retain, even though valid. Occasionally he missed an important unit or miscorrelated it. A few of his names are preoccupied or otherwise invalid, and a few new ones have been introduced.

CONTINENTAL MISSISSIPPIAN STRATIGRAPHY

The Mississippian system in eastern Pennsylvania is generally succeeded throughout the Anthracite Fields by the Pottsville conglomerate, which marks the beginning of the coal measures. The base of the Mississippian system is drawn at the lowest beds assigned to the Pocono formation. This, in the Anthracite Fields, may be marked by the Griswolds Gap conglomerate (I. C. White's term) or its close equivalent. Farther west, the Knapp sandstone and conglomerates are thought to occupy approximately this position, but full verification of this hypothesis remains to appear. In those sections where neither Knapp nor Griswolds Gap crop out, the base of the system must be drawn at the bottom of the lower, massive member of the Pocono, sometimes referred to as the "Berea", but to which I have recently given the name Second Mountain member (258). The Mississippian-Devonian contact is thought to be disconformable over much of the State of Pennsylvania.

Mauch Chunk formation.—The Mississippian system is divisible into two "formations," the Mauch Chunk and Pocono. The upper formation, the Mauch Chunk, is a succession of red sandstones and shales (11), ranging in thickness from 0 to 1600 feet or more; it may be nearly twice that thickness in the Susquehanna Valley. Northward and northwestward the Mauch Chunk diminishes from a recorded maximum in Carbon County until at Pittston it is doubtfully contained in a few feet of non-red shale. Farther northwest the Pottsville is reported in direct contact with the Pocono. Apparently, this contact is always a disconformity. The formation is widely spread throughout the Anthracite Fields and along the Allegheny Front and the Broad Top Field and presumably underlies a large part of western Pennsylvania where marine limestones, unknown in the east, appear at its base. It has not been successfully subdivided in the east and is everywhere nearly devoid of organic remains.

Pocono formation.—The Pocono formation consists mostly of massive, gray sandstone and conglomerate beds which are thickest (at least 1500 feet) and probably coarsest (save for the Griswolds Gap conglomerate) in Second Mountain from the Lehigh to the Susquehanna. The formation thins northwestward and northward and simultaneously becomes finer-grained. Like the Mauch Chunk, the Pocono in the east was formed in fresh-water; unlike the Mauch Chunk, which is nearly barren, it carries a varied flora and some thin coal beds. The Pocono is tripartite. At the base occurs locally the Griswolds Gap conglomerate, and the Knapp (and perhaps an extension of the Corry or Berea) may occupy much the same position in the northwest. Continuous with these or persisting where they are not distinguished is the massive, lower Second Mountain member. The very similar Cove Mountain member forms the upper third of the Pocono. The middle third is made up of less massive, more flaggy to platy sandstones with fewer pebble beds. To this the name Peters Mountain member has been given. This trifid character of the Pocono is of important correlative value. The top member is said to be more or less transitional into the Mauch Chunk. Interpretations given below tend to discredit the idea of a supposed prominent Pocono transition downward into the Catskill.

CONTINENTAL DEVONIAN STRATIGRAPHY

Catskill facies

The Catskill magnafacies or facies group includes some few marine beds, but they are a minor part. It is dominantly continental, almost entirely so in northeastern Pennsylvania. Therefore, subdividing is done largely upon lithology, for diagnostic organic remains are rare. The Devonian fresh-water members are said to be distinguished from the Mississippian by the floras. David White (225) remarked that the Devonian continental beds are characterized by the *Archæopteris* and the lower Mississippian by the *Triphyllopteris* flora. There is confusion regarding these plants. *Archæopteris* may, as White stated, be restricted to the Devonian, but the genus has been reported from higher beds up to and including beds assigned to the Pottsville in Maryland and from the Culm of Europe. White himself listed it from beds believed now to be of post-Devonian age. On the other hand, Darrah (personal communication) is convinced that *Archæopteris* is never found in the Pocono of Pennsylvania. It seems not improbable that we are dealing with several forms which have not been sufficiently studied to distinguish them. Because of this confusion, it is difficult at present to apply paleobotanic evidence to distinguishing the Devonian from the Mississippian, nor can we safely cite early references on this topic. Particularly, in reading Lesquereux (138), it is impossible, because in many instances his descriptions of localities are too vague to tell whether he is discussing the Catskill or the Mauch Chunk red beds. Nevertheless, it seems clear that Lesquereux did recognize *Archæopteris* in some of our red Catskill members, and that those from which he reported it are all of post-Honesdale age, that is, the Cherry Ridge and Mount Pleasant red shales. In this case the plants reported should be of late Canadaway or Conewango age.

Though short of fossils, the Catskill is rich in lithologic units. There is an astonishing recurrence of rock types in an alternation of red and non-red members whose repetition may be recognized in any fairly complete section in northeastern Pennsylvania, but without a nearly entire sequence it is often impossible to identify them. These several units can be traced in nearly all instances into marine formations, so that their relative ages have been ascertained. A marked exception to this rule is the highest division, the Mount Pleasant red shale, which pinches out westward beneath the succeeding Mississippian sandstones and conglomerates. The areal distribution of these units is shown in the map, Figure 72. Most of them form bands concentric to the Northern Anthracite Field. Some pass over into New York and back, and a number can be traced southward about the Southern Anthracite Field. The natural assumption of course is that most of them pass under the anthracite basins, an assumption which we shall see is fully justified, even though there be changes during the subterranean passage.

Mount Pleasant red shale.—The name Mount Pleasant, introduced by I. C. White (226), is retained in the Mount Pleasant red shale. It was named for the village of Mount Pleasant in Wayne County, but that town is now called Pleasant Mount. However, the name remains appropriate as the township is still Mount Pleasant and contains the type locality. It is the highest red member of the Catskill. White applied Mount Pleasant to more than one unit, including a conglomerate and red shale under the one name. It is here restricted to the shale and embraces the beds from the base of the Pocono to the top of the Elk Mountain sandstone. This includes in Wayne County the highest red beds below the Griswolds Gap conglomerate, which White thought probably were Devonian-Mississippian transition strata. I believe they are assignable entirely to the Devonian. The dominance of red in this unit ties it in with the Devonian rather than the Pocono. Detailed studies point to a unity in this formation over a wide area. The included conglomerate recorded by White seems local, red shale and sandstone dominating. The Mount Pleasant is well exposed along United States Highway 6 about Waymart, Wayne County, and thence west to the State Hospital. The total thickness here is about 500 feet in the type region.

The Mount Pleasant red shale thins northwestward and disappears in the Devonian-Mississippian disconformity at the base of the Pocono. South of Wayne County, it has been recognized on the Pocono Plateau, but not surely beyond that region for it merges with the Cherry Ridge red member (*q. v.*) as the intervening Elk Mountain greenish-gray sandstones dies out. White (see quoted sequence, page 267) thought he had Mount Pleasant on the Lehigh River, but his No. 6 bed is probably the Griswolds Gap conglomerate. The 500 to 700 feet of red and green beds below may very well equal the Mount Pleasant of Wayne County, but are in part also the upper portion of the Cherry Ridge. Nothing in the section by White fits the Elk Mountain sandstone, nor have I observed any bed that I myself would so correlate. Winslow's record (see quoted sequence, page 268) of the section comports with this belief.

Westward from Wayne County, the Mount Pleasant dies out. This is a gradual pinching out illustrated in the section, Figure 74. As the Mount Pleasant goes out, the basal Mississippian (Knapp (?) or its equal) rests directly upon the Elk Mountain or its correlate, the Oswayo "shale." Because of this situation, the Devonian age of the Mount Pleasant may be questioned. Lithologically, it allies itself with the Catskill facies rather than the Pocono. Its separation from the Pocono is drawn upon a marked lithologic break indicative of a sudden change in sedimentary conditions, from red to coarse gray or whitish conglomerate.* No angular discordance at the base of the Pocono has been observed. What, if any, the marine equivalent of the Mount Pleasant may or may not have been I do not know. Caster (33) recognizes a Devonian-Mississippian disconformity in the northwestern marine beds. If his highest marine Devonian is the Oswayo, which I correlate with the Elk Mountain, and if the Knapp is basal

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* I. C. White at first (226,228) doubted the correctness of calling the Mount Pleasant Devonian. However, in (229), he assigned the Griswold Gap conglomerate to the basal Pocono, a designation which I follow.

Pocono, there is an hiatus here with no marine beds of Devonian age equal to the Mount Pleasant. Evidently, if these deductions and correlations be correct, the disconformity which Caster recognizes between the Devonian and the Mississippian corresponds precisely with that which I recognize between the Oswayo (or Elk Mountain) and Pocono and into which the red Mount Pleasant wedges from the east. When my studies began I had no notion of these correlations, nor did I tie in the dying out of the Mount Pleasant with the disconformity recorded by Caster until some time after I realized that there is a disconformity at the base of the Pocono in the same stratigraphic position.

Elk Mountain sandstone.—The Elk Mountain sandstone consists of green to grayish-green, flaggy sandstone, extraordinarily cross-bedded, with some few shale interbeds. This cross-bedding is its most distinctive feature and is generally more strongly developed and more persistent than that observed in any other of the non-red Catskill units, although all these show some tendency to be cross-bedded. I. C. White (226) proposed the name from the Elk Mountains in Susquehanna County, around the base of which the formation extends. He seems to have included under the term beds better assigned to adjacent red formations. I restrict the name to the non-red, cross-bedded flagstones. Good exposures are common, but complete sections are rare. On United States Highway 6 near Prompton in Wayne County, the Elk Mountain sandstone may be seen in the hills north of the road, and there are several showings in southeastern Susquehanna County and westward. The Elk Mountain sandstone persists from Wayne County southward to Monroe County, and then dies out and is not known west of the Pocono Plateau. (Figure 72.) Its absence, as observed, prevents separating the Cherry Ridge and Mount Pleasant red units, particularly in the Lehigh Valley. West from Wayne County, it continues through our northern tier of counties to Potter. The Elk Mountain sandstone then passes gradually into the Oswayo sandy shale of western Potter and McKean counties. Probably it runs southward into Clinton, where the Mount Pleasant is absent and the Pocono rests directly upon beds of Elk Mountain lithology. The formation is remarkably persistent if this correlation be true. Its thickness changes are small, 150 feet in Wayne to an average of about 200 feet westward to Bradford County, where it thins a trifle. It must be observed that these statements are in disagreement with the findings of Fuller and Alden (96, 97), but their "Oswayo" and "upper Cattaraugus" come under a different interpretation from mine. In Potter County additional changes begin. Cross-bedding dies out, the color is more olive or olive-brown than green. Marine life appears in a fossiliferous conglomeratic band at the base. This condition grows more dominant into McKean County until the characters of the Elk Mountain sandstone are gone, and those of the Oswayo sandy shale have superseded them.*

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* In my previous description of the Catskill facies (250) I mistakenly called this the Salamanca conglomerate. It is more probably somewhat near the Tuna-Killbuck conglomerate and may even be a close equivalent of the Roystone ("Flatiron") coquinite farther west.

Cherry Ridge red beds. I. C. White (226) also introduced the name Cherry Ridge, but his type locality in Wayne County is unsatisfactory as the exposure is incomplete and indifferent. There are no good exposures of this unit. White divided the Cherry Ridge into five members, to each of which he applied the name Cherry Ridge combined with an appropriate lithologic term. Most of these units are local and not worth mentioning. Cherry Ridge red beds here designates a dominantly red succession of somewhat varied lithology which separates the Elk Mountain from the Honesdale sandstone. White reported 170 feet for the Cherry Ridge in Wayne County, and said that it thickened southward, a statement I have verified. It is at least 300 to 375 feet thick on the Pocono Plateau and between 300 and 400 feet on the Lehigh River, although at that point the upper limit is uncertain because of the lack of the bounding Elk Mountain sandstone. Presumably it continues west to the Juniata and Susquehanna valleys and Perry County. West from Wayne County, the Cherry Ridge attains a thickness of about 600 feet in the Susquehanna Valley. On into Wyoming County some red beds of Honesdale age may be included, and it is possibly 1,000 feet thick in parts of Bradford and Tioga counties. Still farther west it slowly thins to become the Cattaraugus red member in western Potter and McKean counties. This thinning is the result of the already described continental off-lap westward or northwestward with displacement of marine by fresh-water sediments.

Two units of the Cherry Ridge need comment. White recorded a conglomerate which he distinguished by its red quartz pebbles. This is in the upper part of the Cherry Ridge and is a persistent bed across the Pocono Plateau, where it forms small ridges and hills concentric to the eastern escarpment. There is no doubt of its being part of the Cherry Ridge for it occurs too far east of the Plateau to be assigned to any other formation of Catskill lithology. I named it (250) the Pimple Hill conglomerate for exposures in knobs of that name in Monroe County. The Pimple Hill conglomerate crops out on the Lehigh River, where, however, other similar conglomerates may show, particularly southeast from Mauch Chunk in the first ridge north of Packerton and the corresponding Bear Mountain across the river to the east. Possibly more than one similar conglomerate is present on the Plateau, but the Pimple Hill is thought to be the most persistent. West of the Lehigh River the Cherry Ridge carries one or more such conglomerates, but as they are essentially at the same zone and of very like lithology, the name Pimple Hill is retained for any such found. They extend all the way into the Susquehanna Valley in Dauphin County. The Pimple Hill has not been discovered west from Wayne County in our northern areas (Figure 75).

Among the Cherry Ridge members, White (226) reported a "limestone" in its lower part. The use of the term is misleading, but the bed (or beds) may be important. His excellent description runs, "It is an agglomeration of chips of slate and shale—fish bone fragments—pieces of fossilized wood—and often a large quantity of sand—all cemented together with lime." Light-gray if fresh, this glomerate weathers black and pitted. Its residual boulders are common objects in the northeast. "Fish beds" occur in other north-

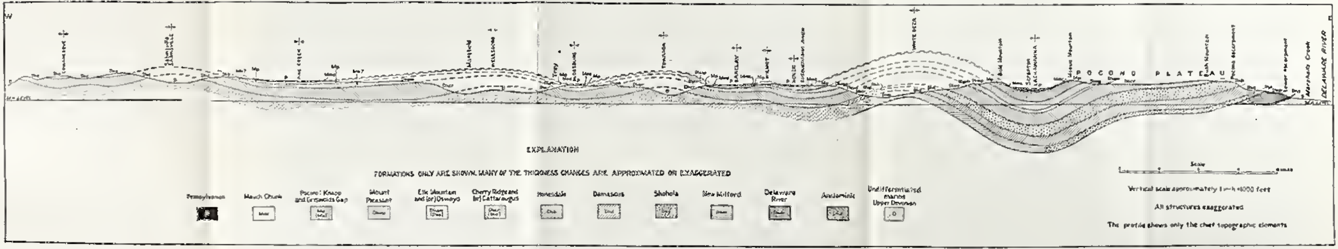
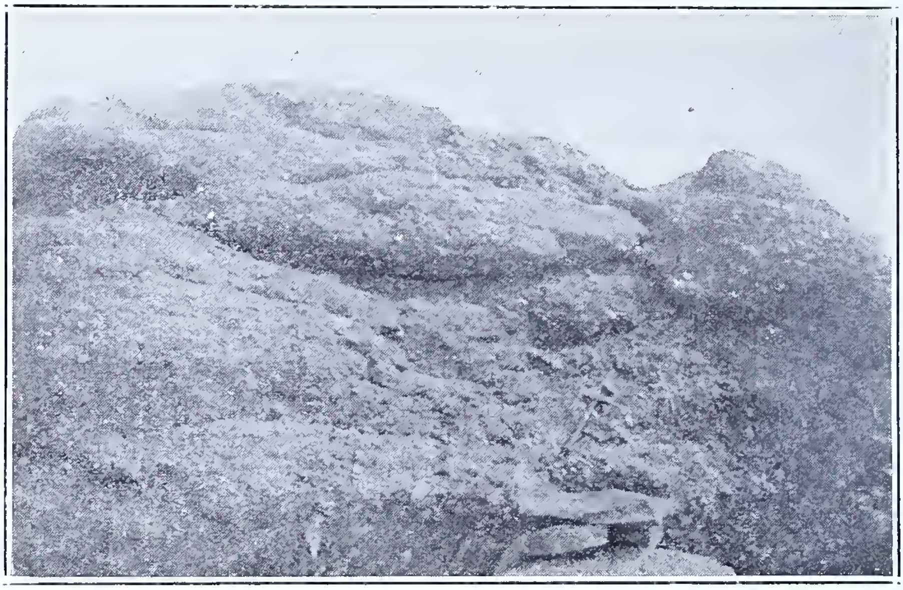

W
E
POCONO PLATEAU
DELAWARE RIVER
Marshalls Creek
Lower escarpment
Pocono escarpment
Bald Mountain
Scranton
LACKAWANNA
Moosic Mountain
EXPLANATION
FORMATIONS ONLY ARE SHOWN. MANY OF THE THICKNESS CHANGES ARE APPROXIMATED OR EXAGGERATED
Pennsylvanian
Mauch Chunk
Pocono: Knapp and Griswold Gap
Mount Pleasant
Elk Mountain and (or) Oswayo
Cherry Ridge and (or) Cattaraugus
Honesdale
Damascus
Shohola
New Milford
Delaware River
Analomink
Undifferentiated marine Upper Devonian
Scale
Vertical scale approximately 1 inch = 4000 feet
All structures exaggerated
The profile shows only the chief topographic elements

Figure 71. East-west geologic section across northeastern Pennsylvania, illustrating Catskill sequence and relations.

eastern Catskill units. White described that of the Cherry Ridge, but his words apply to them all. Perhaps there are several in the formation. The type is that which White denominated "a limestone." I named it (250) the Dyberry glomerate for its appearance on Dyberry Creek and in Dyberry Township, Wayne County, where fragments of the rock strew the surface. It is probably in place in the headwaters of Dyberry Creek near Cold Spring. It is a fairly useful key bed, as White knew, and I have found it of limited value as a guide to the Cherry Ridge formation in Susquehanna, Wayne and parts of Bradford and Wyoming counties. West of Bradford, the Dyberry glomerate is lost, and it probably gives out in northern Monroe County, for no evidence of it was seen in place in the southern part of the Pocono Plateau. Such pieces as were found there and even farther north probably were brought with the local drift. Simultaneously with the failure southward of the glomerate as a marker for the Cherry Ridge, the red Pimple Hill conglomerate becomes a useful key to this Catskill unit.

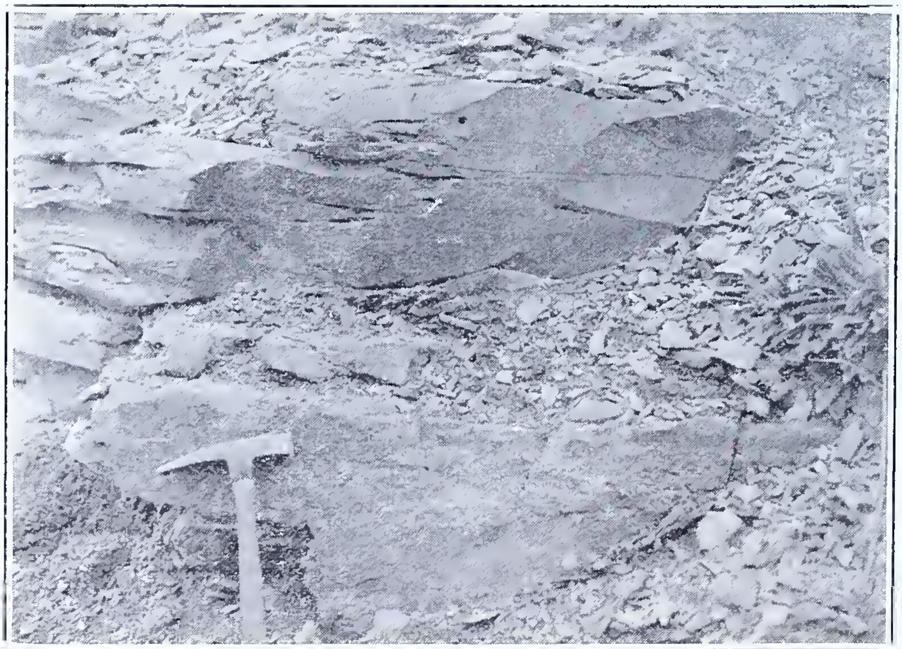
South of Terrytown, at Austinville and at other places in Bradford County in the lower part of the Cherry Ridge red beds are many fish remains. These may tie in with the fish-bearing Dyberry glomerate toward the east. The fish in the two regions where they occur in the Cherry Ridge are in decidedly unequal states of preservation. Those in the east in the glomerate are highly comminuted. None of them was found in good enough condition to permit specific or even generic identifications. In Tioga County a few fish are found in the red beds, but the fish-bearing portion has gone over largely to marine strata. In intermediate Bradford County, fish are found fairly entire, permitting more accurate determination (Figure 76).

The remains in the red beds are thus best preserved in those occurrences nearest the marine environment; poorest farther inland. If the fish primarily dwelt in fresh water and migrated or wandered or were washed to sea, such would hardly be the observed conditions of the fossils. Such a theory I once supported, but was forced to abandon it with additional studies of the distribution of these broken fish fragments. Hence, I suggested that these early fish were anadromous. If we assume that they dwelt chiefly in the sea or in a brackish environment near shore where we find them associated with inarticulate brachiopods and fragments of plant remains, they may be supposed to have ascended the rivers to spawn and there have died in multitudes. It was suggested in the preceding section of this chapter that a large river may have debouched in this region in late Devonian time. If such existed with its distributaries spreading across a wide, low delta, the situation should have been ideal for up-stream migrations. The numerous remains of defunct individuals massed together in the spawning grounds might then be reworked by currents and laid down with mud chips, fragments of shale, sand, and what not as the Dyberry glomerate of the Cherry Ridge shale On the other hand, those fishes which died in the calmer, salt or brackish waters of estuaries, off the river mouths or beyond, suffered no such breaking up in currents, but in relatively quiet conditions may be supposed to have been buried more or less entire and so preserved. This may further imply that during the spawning season



Photograph by Bradford Willard

Figure 75. **Pimple Hill conglomerate on Bear Mountain, Carbon County.**



Photograph by Bradford Willard

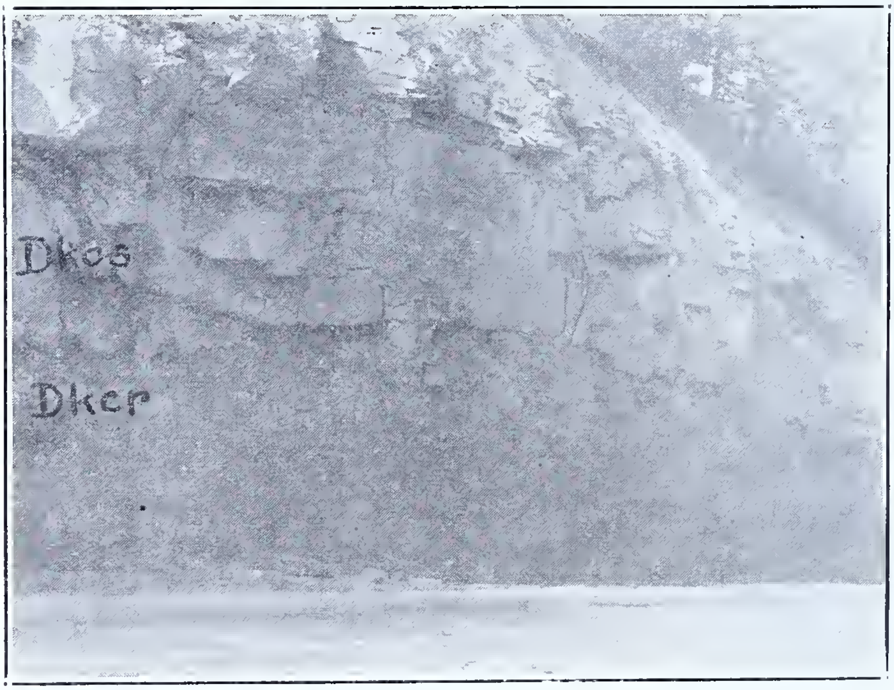
Figure 76. **Fish, glomerate, Catskill continental beds, Susquehanna County.**

the individuals roamed in schools, but at other times went about singly, as the better-preserved fish are usually solitary or at best but a few individuals cluster together.

The Cherry Ridge, I remarked, passes west into the Cattaraugus which is assigned to the Conewango group in western Potter and McKean counties, where it is soon to become marine. There is no sharp means of separating laterally the Cattaraugus from the Cherry Ridge. This applies to the red beds which should lie above the level of the Panama conglomerate were that unit present eastward. But only after most or all the lower part has become marine westward, does the Panama appear at its base, setting off the true Cattaraugus in McKean and western Potter counties. Eastward in eastern Potter and Tioga counties, the lower part of the Cherry Ridge is probably equal to the Chadakoin or to the whole Conneaut group. Apparently the Bloomsburg of Timothy Conrad (77) is our Cherry Ridge, but his description is uncertain and nearly useless. Fuller and Alden called "all" the red beds in northern Tioga County "Cattaraugus." Obviously this is wrong, for they thus embraced strata somewhat older than the Panama, which marks the base of the Cattaraugus to the west. If a term must be applied to these red strata, Cherry Ridge is logical. Furthermore, they are not divisible. Chadwick's theory (49) is not in agreement with this, but it is obscure whether he took account of the equivalent Cattaraugus beds eastward across Tioga County. My correlations are based chiefly upon lithologic changes. So, in the marine-to-continental change east from Potter County, a downward progression of Chadakoin lithology, pink or plum or chocolate-shaded beds, is observed. I have commented on such a change in central and eastern Pennsylvania in beds of greater antiquity. The phenomenon keeps pace with the base of the eastward-descending Cherry Ridge red beds. In Tioga County I found no *Camarotocchia duplicata*, indicative of the Conneaut group. Perhaps the red beds here are really older than they are to the east and west. In western Bradford County, the basal Cherry Ridge may belong to the upper Canadaway. It seems to be passing over into marine beds with *Athyris angelica* common. The red beds of the basal Cherry Ridge are above the Luthers Mills coquinite in central Bradford County, and are separated therefrom by beds correlated with the Damascus and Honesdale formations farther east.

The Cattaraugus in western Potter and McKean counties and its correlate in Tioga and western Bradford counties, the higher beds of the Cherry Ridge, carry green strata in the top. These are barren and lithologically very like the eastern Oswayo and the Elk Mountain sandstones. Indeed, where the coquinite or conglomerate is missing or the erosional break sometimes seen between the Oswayo and Cattaraugus (Figure 77) is absent or concealed, it is nearly impossible to separate the two. Furthermore, about Coudersport, particularly in quarries just west of the town, a heavy, green sandstone 10 to 20 feet thick appears about 100 feet below the base of the Cattaraugus. This I named (250) the Coudersport member. It persists into Potter, Tioga and probably McKean counties and perhaps even as far as Cameron, Clinton, Lycoming and Sullivan counties. A limitedly useful key bed, it must not be confused with the Oswayo which it closely resembles, though perhaps generally it is less cross-bedded and more massive.

Thus, the Coudersport, eastern Oswayo (or Elk Mountain), and the green beds in the upper Cattaraugus are similar. Where the Pocono and Knapp have been eroded, or at least are absent, it may be hard to identify the Oswayo, especially in an incomplete section. Also, in partly exposed sections or in barren rocks where the Panama or other conglomerates or distinctive, key beds cannot be determined, it is nearly hopeless to differentiate the three greenish units. Therefore, I believe that the supposition that the Oswayo in Tioga County is older than that in McKean is not sustained by field evidence. Presumably, the Oswayo, so-called, in northern Potter and Tioga counties is green Cattarugus, Coudersport, or, not improbably, a yet older development of this locally recurrent facies which has not been identified as an independent unit. More southerly sections indicate the true Cattaraugus-Oswayo-Knapp relations. From these lines of evidence, I doubt if there be any true Oswayo (or Elk Mountain) in northeastern Potter and northern Tioga counties.



Photograph by Bradford Willard

Figure 77. **Unconformable contact on the highway northeast from Bradford, McKean County, between the overlying Oswayo (Dkos) sandstone and the underlying Cattaraugus (Dker) shale.**

Honesdale sandstone.—The Honesdale sandstone is another of I. C. White's units. He named it from good exposures at and near Honesdale, county seat of Wayne County, and defined three divisions. At the top he recognized a 25-foot white sandstone, in the middle a 40-foot red sandstone, and at the bottom a 23-foot gray sandstone. These units are local and of little importance, although the middle red member is a convenient means of "spotting" the formation in the immediate vicinity of the type locality. Greenish and gray flags dominate and much resemble the Elk Mountain sandstone though they are less prominently cross-bedded. Red beds occur here and there. Often the gray sandstone is conspicuous when weathered nearly white. About the type locality, there is close to 100 feet of the Honesdale. It thickens and grows coarser, pebbly and grayer southward, so that it becomes practically identical with the Pocono in appearance. It maintains these characters as a continental formation and increases to 500 or 600 feet of gently northwest-dipping beds in the eastward escarpment of the Pocono Plateau. It turns west and thickens along the south edge of the Plateau and there rises in steeply-dipping beds along the south side of Bear Mountain and the first prominent ridge north of Packerton across the Lehigh (see Mauch Chunk topographic sheet). Farther west, as below Pottsville on the Schuylkill, this ridge becomes the southern crest of double-crested Second Mountain. Followed still farther west, the sandstone gradually loses its ability to support the ridge, but is still recognized at the Susquehanna River north of Harrisburg. There, in conjunction with the Pimple Hill conglomerate, it tends to produce a small shoulder along the south side of Second Mountain and the north side of Peters Mountain (opposite limbs of a great syncline). It flanks Cove Mountain as Pine Ridge in Perry County. The Honesdale has not been certainly found in the Susquehanna Valley north of Peters Mountain, and is lost northeastward along that ridge. In the Susquehanna Valley above Harrisburg, it is usually a gray to greenish-gray, heavy sandstone occasionally carrying carbonized stems of land plants. West from Scranton and from Tunkhannock down the North Branch of the Susquehanna River to Pittston, the Honesdale loses its characteristic color, growing red and merging with the overlying Cherry Ridge and perhaps with the older Damascus as massive, red sandstones which produce small ridges. The great cliffs along the river above West Pittston probably are composed of red Honesdale and Cherry Ridge red sandstones, joined into a single unit. The Honesdale is well known northwest of the Northern Anthracite Field in Susquehanna County and beyond. There, it and the Elk Mountain as well, form small terraces or ridges skirting the coal basin.

In Susquehanna and Bradford counties, the Honesdale becomes marine, according to occasional fossils found in the Susquehanna Valley in this sandstone, but fossils are never common in it east of central Bradford County. There, near Franklindale, the marine equivalent of the Honesdale supplied the following (*Cf.* p. 254):

Crinoidea, columnals
Stropheodonta demissa (Conrad) ?
Schuchertella chemungensis (Conrad)
Productella lachrymosa var. *stigmata* Hall
Camarotoechia sappho Hall
C. stevensi Hall
C. contracta Hall
C. sp.
Cryptonella eudora Hall
"*Spirifer*" *disjunctus* Sowerby
"*S.*" *mesacostalis* Hall*
Athyris angelica Hall
Grammysia elliptica Hall
Sphenotus contractus Hall
Leptodesma propinqua Hall
L. orcus Hall
L. becki Hall
L. sociale Hall
Schizodus sp.
Orthoceras sp.
Pisces, undetermined spines

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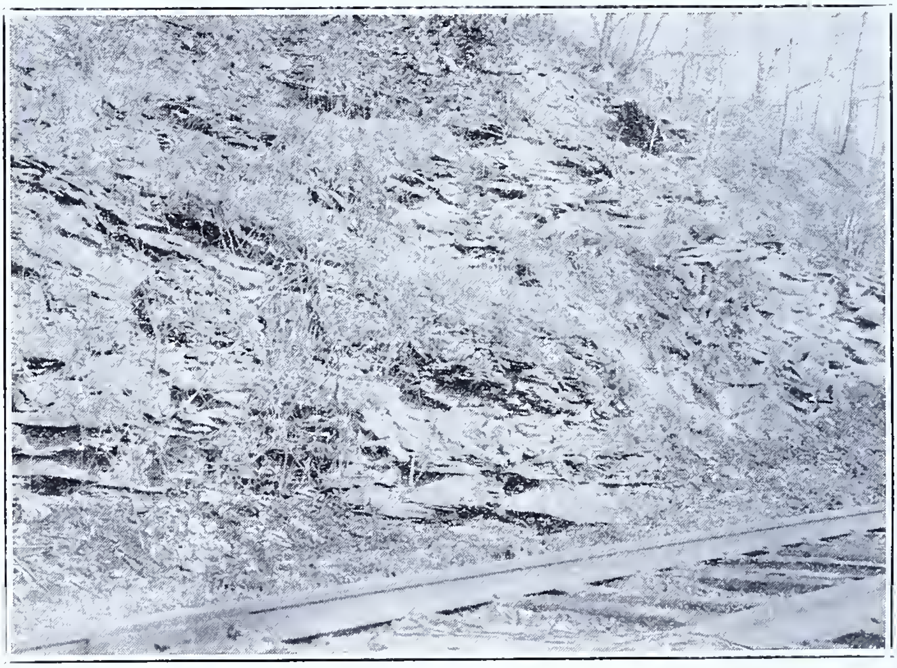
* Some of the specimens identified as this species may actually be "*S.*" *williamsi* Hall and Clarke. These fossils are younger than the Franklindale limestone.

Another, less numerous, faunule was taken from these same beds, but farther along the highway west from Burlington:

Crinoidea, columnals
Fenestella sp.
Camarotoechia sappho ? (Hall) juvenile
C. sp.
Cryptonella eudora Hall
"*Spirifer*" *disjunctus* Sowerby
Athyris ?
Phyllocarid, undet.

When the above lists are carefully checked with those cited by Chadwick (51), it is not hard to demonstrate that the faunules represent early post-Chemung time. This is implied by the presence of *Productella lachrymosa* var. *stigmata, Athyris angelica* and *Sphenotus contractus.* Nevertheless, from the stratigraphic position, the beds cannot be far above the top of the Wellsburg formation (upper Chemung). The occurrence here of *Cryptonella eudora* and "*Spirifer*" *mesacostalis* (or "*S.*" *williamsi*), however, restrict the age to not later than Canadaway. Through intermediate stations, it is possible to establish that these beds are the true correlate of the Honesdale farther east. From eastern Bradford County on into Wyoming, chiefly along the Susquehanna Valley, the Honesdale sandstone, is exposed in cliffs, and tends to form particularly rough and craggy faces, easily recognized and conspicuous. This character continues west, even into beds that carry marine fossils, all the way to Troy.



Photograph by Bradford Willard

Figure 78. **Fossiliferous "Chemung" on Erie Railroad near Tioga, Tioga County.**

The fossils of the Honesdale and the Luthers Mills coquinite are closely allied, but the former are somewhat younger. Those of the Honesdale occur near the base of the Cherry Ridge red beds and so establish their correlation as upper Canadaway. The Damascus red shale is also present east of Troy and carries there a few marine fossils, but they were so much broken up that identifications were unsatisfactory, except for "*Spirifer*" *disjunctus* and *Athyris angelica*. Fragmentary fish plates also occur. A generalized sequence for the beds between Burlington and East Troy is:

	Feet
Cherry Ridge red beds ("Blossburg")	700
Honesdale sandstone (marine)	100
Damascus red shale (partly marine)	25?
Concealed	25?
Luthers Mills coquinite	40

Across northern Bradford County, no close correlation has been made, but the Honesdale is known north of Troy and may be prolonged into northern Tioga County. It is probably older than the Cuba sandstone, and *Camarotœchia duplicata* was not found in this unit. These relations will be further discussed below.

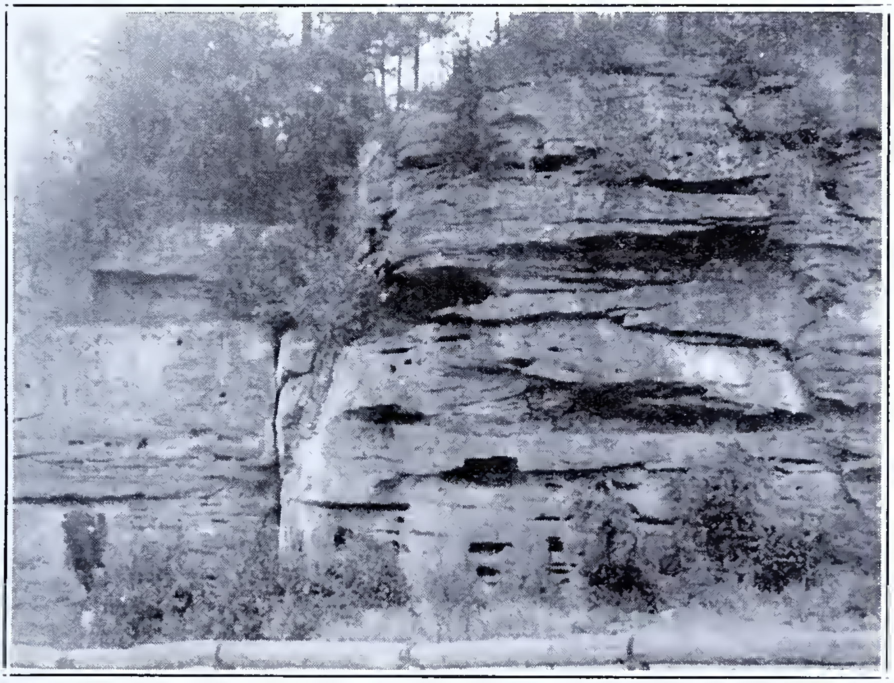
Damascus red shale.—The Damascus red shale lies immediately underneath the Honesdale in northeastern Pennsylvania and was recognized by I. C. White (226) who referred to it as the "Montrose". Vanuxem (217) had used this name forty years before White's time but in a different sense. Probably, White thought he was working with the equivalent of what Vanuxem called "Montrose", but this was not the case, as has been demonstrated separately by both Chadwick and me. Neither, as White thought, are the Damascus and Honesdale equivalent, although each is correlated with a part of the Canadaway group. Palpably White erred in that he confused the Honesdale with the New Milford in central Susquehanna County. This was made more pronounced in that he appears not to have realized that the base of what he called "Chemung" rises westward. White chose ill the type locality for his "Montrose", for the formation is rather poorly exposed about Montrose in central Susquehanna County. East and northeast from Honesdale the Damascus thickens. It crops out about Beach (or Beech) Lake along the main highway north and on the Delaware River about the town of Damascus, for which I named it (250). At Montrose the formation is probably hardly 100 feet thick, although White reported 180 feet. It is 200 feet in central Wayne County, and grows to not less than 400, perhaps considerably more, at the type locality on the Delaware. The Damascus is correlated with certain red beds exposed at the foot of the Pocono escarpment in Monroe County and probably includes those which are seen along Lake Wallenpaupack. However, at the lake the drift is heavy, so that correlation is obscured; and local faulting and tilting of the beds confuse the issue. South and west from Monroe County, the formation continues to thicken, but its total thickness is not closely establishable, although it must constitute a large percentage of the red beds below the Pocono in the Lehigh Valley. Of these there are 3,000 feet, and they are still considerable on the Susquehanna. Although assigned principally to the Damascus in both places, it is correct to presume that the Shohola also is represented. White (226) cited 2,000 feet of his "Montrose" along the Lehigh River, but he did not differentiate the Honesdale and so assigned 1,000 feet of red and non-red interbedded shales, etc., to the Cherry Ridge. His numbers 16-30 are now included in the Honesdale. In Perry County, Claypole (72) gave a thickness of at least 6,000 feet to the red Catskill, but the facies is 1,000 to 1,500 feet thinner, a discrepancy readily explained through structures now exposed, but concealed in his day. Nevertheless, in Perry County, a Chemung faunule has been discovered in the Kings Mill sandstone (71, 72, 250 *et. al.*) some 500 feet above the lowest red beds, so that the Damascus, which is post-Chemung, must be restricted to the higher red beds at least. As the Shohola below the Damascus is largely of Chemung age, it may approximately equal the Kings Mill sandstone and the 500 feet of red beds below it.

Where the Honesdale cannot be clearly distinguished west of the southern half of the Northern Anthracite Field, the Damascus formation merges completely with the overlying red beds of the Cherry Ridge formation. This relation has been cited under the description of the Honesdale. West of Wayne County, where the Damascus and Cherry Ridge are divided one from another by the Honesdale, the lower of the two red units is a fairly constant entity about 100 feet thick. It is clearly recognizable in the Susquehanna River cliffs of eastern Bradford County, but on south into Wyoming and beyond where the Honesdale (*q. v.*) becomes red, the distinction is less apparent. The Damascus passes westward into marine beds near the same lattitude as does the Honesdale in central Bradford County. East of Troy in the valley of Towanda Creek, one may view this transition. The fossils collected in the marine equivalent of the Damascus are essentially identical to those found in the marine Honesdale of this locality. Of all the red Catskill units, the Damascus is the lowest persistent one. It is intermediate between the Honesdale sandstone and the top of the New Milford formation below, and its fossils are nearly related to both, so that its age is held to be Canadaway. Despite its thickening eastward to the Delaware River, it is still probably all of Canadaway age there, as will appear more clearly when the discussion of the Shohola formation is read.

Shohola formation.—In Wayne and Pike counties, seen chiefly in the Delaware Valley, below the Damascus red formation is a series of continental beds which I recently named the Shohola formation (250) from Shohola on the Delaware below the mouth of Lackawaxen Creek. This formation is composed of two members. Above is the thin Paupack and below the thick Barryville member. White knew and named the Paupack sandstone from a 25-foot exposure near Hawley on Paupack Creek. These rocks appear again on the creek below the new dam of Wallenpaupack Lake at Hawley, and at several places in northeastern Pennsylvania, particularly in abandoned stone quarries near Tedyuskung Lake, and across the Delaware about Narrowburg, New York. The rock is massive, blue-green sandstone, gray- or brown-weathering, with a litle shale of the same tint. The type Paupack of White underlies his "Montrose", but he found it to rest upon 200 feet of red and green shale and sandstone which he said were so uncharacteristic that he hesitated to propose a name for them. The true relations may be seen today in near-by areas. North of the

Anthracite Fields, the Damascus rests upon the New Milford formation whose top is early Canadaway in age. Therefore, in central Wayne County, where the Damascus rests upon the Paupack sandstone, that unit should equal the upper part of the New Milford formation, if indeed it does not equal considerably more thereof.

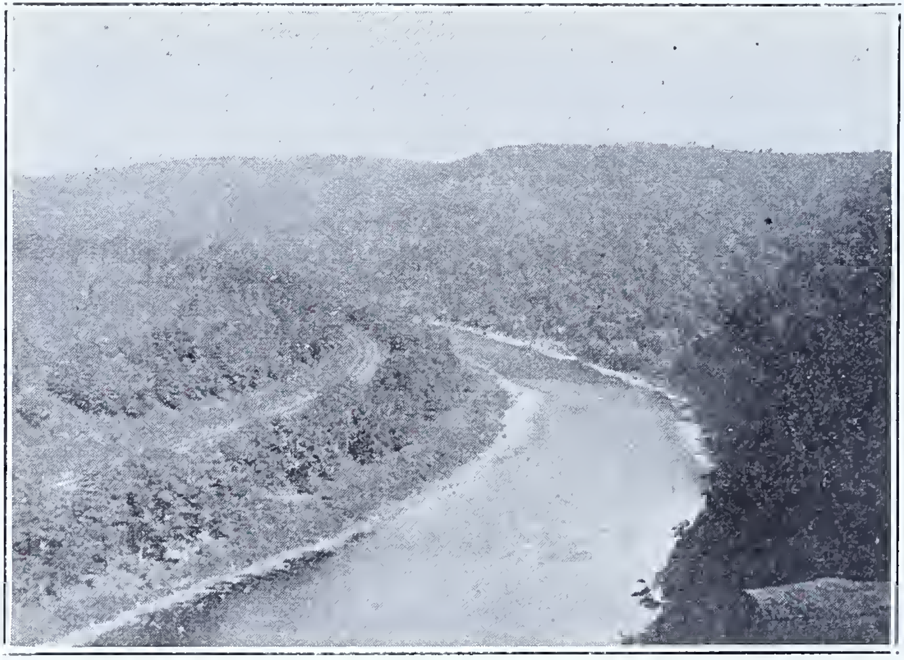
Betwixt the Paupack and the Delaware River flagstones, to be described subsequently, on the Delaware River in Pike County, but better shown in New York across the river in the vicinity of Barryville, the lower member crops out. It is named for Barryville, New York (250) and is made up of not less than 700 feet of shales and sandstone, gray to olive in color, cross-bedded, and weathering in most exposures to deeply pitted surfaces. Red interbeds are known and also lenses of glomerate and layers of mud chips and fish fragments. This is the member below the Paupack sandstone which was so enigmatical to White. I have grouped the Paupack and Barryville members under the formational heading Shohola because they fall naturally together between the red Damascus above and the subjacent Delaware River formation whose age is unquestionably middle to late Portage. The Shohola is Chemung save for at least the upper part of the Paupack which is correlated Canadaway in age. In its entirety it represents all the marine Chemung of the northwest plus an undeterminable amount of the lower Canadaway. In the marine beds of Susquehanna and Wayne counties, the Chemung fauna survives the lithologic change from the shaly lower Chemung or Cayuta



Photograph by Bradford Willard

Figure 79. **Cliff of Barryville sandstone near Barryville, N. Y. Picture illustrates the characteristic bedding and deep pitting.**

to the more massive, upper Chemung (Wellsburg), equivalent in part to the New Milford formation as here used. Consequently, a similar change from the relatively shaly Barryville to the massive Paupack seems to have correlative and chronologic significance. The nonmarine correlative of much of the Chemung, the Barryville, has the lithologic habit of the still younger continental beds, in that it consists of cross-bedded, red and greenish strata. It has been found feasible to follow most of our higher Catskill units around the northern end of the Lackawanna basin. The Barryville member may be differentiated from the Delaware River flags below it in the Delaware River valley, by the fact that it carries red partings, a feature apparently absent from the older beds.



Photograph by Bradford Willard

Figure 80. **View north along the Delaware River from Hawks Nest, N. Y., type region of Delaware River flags.**

The Shohola formation has been recognized across Pike County west from the upper Delaware Valley. The Paupack loses its identity, and the Barryville member either thins or turns red and is indistinguishable from the overlying Damascus red formation, or takes on the character of and merges with the Delaware River flags so that it is not differentiated west of central Monroe County along Brodhead Creek. This remark is drawn from field observations, albeit the drift is heavy, the beds produce no noticeable topographic expression, and the characteristic lithology of the two Shohola members is not found on the Lehigh. I remarked that at least the lower 500 feet of the Catskill of Perry County is of Chemung age. Also the base of the red beds is a close equivalent of the Portage-Chemung line. Therefore, at least these lower 500 feet of red beds may be the equai of the Shohola of our eastern region.

It is curious that White should have drawn his Delaware River section in such a manner that he placed the Delaware River flags above the New Milford group. Probably, this was because he mistook the marine Upper Devonian of Pike County for true Chemung. Had White not so erred, he might have solved the sequence of the Paupack and Barryville members.

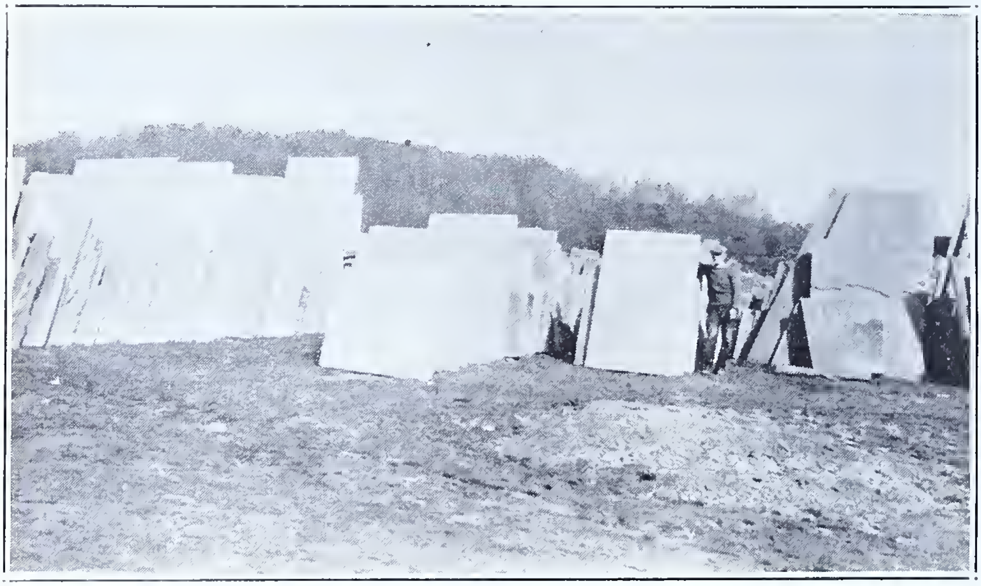
Delaware River flags.—White first defined the Delaware River flags (228). I retain this appropriate name for 1,500 feet of beds along the Delaware River north of Hawks Nest, New York, the type region. White reported only 1,000 feet of this unit, but this figure should be increased by probably 50 percent. Today, exposures are better and limits are more readily definiable than when I. C. White studied the region. Prosser (161) first correctly determined their age. Miscalled Chemung by I. C. White, Prosser demonstrated that they are of Portage age. This I myself have checked. With the coming in above of interbedded red bands, the Barryville member of the Shohola formation is set-off from the Delaware River flags. The Delaware River sandstone itself consists of practically barren, greenish flags devoid of red beds, so far as I have seen. In Pike and Monroe counties, the Delaware River flags may rest upon marine Portage, the Trimmers Rock sandstone, or be separated therefrom over part of the area by the Analomink red shale, but the latter is rather local. Prosser recorded a few marine invertebrates from the Delaware River flags on Brodhead Creek, but I have never been able to rediscover his locality, though I do not doubt the assertion because marine fossils do begin to appear in these sandstones in some abundance in western Monroe County. This is well illustrated in highway cuts near the village of Effort. Along the Lehigh River, 1,200 feet of Delaware River flags was reported by White (228), but part or all of this is marine. West from the Lehigh, the Trimmers Rock and Delaware River sandstones are no longer distinguishable, the latter becoming marine, and the two having identical lithologies even before marine fossils show up in the higher formation. It seems unquestionable that the Delaware River flags in their typical development equal in part or entirely the Oneonta of New York.

Analomink red shale.—The Analomink red shale is a unit of local distribution consisting at its type locality of 100 feet of red shale and very litle sandstone. It was named by me (250) for Analomink village in Monroe County where the beds are well exposed along Brodhead Creek. It appears not to pass beyond the confines of Pike and Monroe counties, for it was doubtfully remarked on the Delaware below Hawks Nest. White (228) confused the Analomink with the New Milford red shale, from which it is separated by a great thickness of beds representing much of the Chemung and a large part of the Portage. The Analomink is locally useful as a key bed separating the Delaware River flags from the Trimmers Rock sandstone.

New Milford formation.—White (226) named the New Milford group, and I retain his term, using it, however, as a formation of several members, typically developed in the region of New Milford, Susquehanna County. The local divisions have been extensively studied by D. S. Harding of Susquehanna who for some years has coöperated with the Pennsylvania Topographic and Geologic Survey. His painstaking studies deserve recognition, and form the basis for most of this discussion of the New Milford formation. However, I need mention little of the details of these beds. White divided the New Milford as follows:

	Feet
New Milford upper sandstone	20
New Milford middle sand and shales	300
New Milford lower sandstone	20
New Milford red shale	100-120
Starrucca olive shales	105

The divisions appear to be valid, and I need comment further on but one, the red shale at the base. This is exposed splendidly in a cut on the Delaware, Lackawanna and Western Railroad at Kingsley, Susquehanna County, and to it in 1936 I gave the name Kingsley red shale (250). As it has some areal distribution and is a convenient datum for determining the interval up to the base of the next overlying red, the Damascus, it is worthy of a distinguishing geographic name. The rest of the New Milford above the Kingsley I have called the Lanesboro member of the formation for exposures in the neighborhood of Lanesboro. In general the Lanesboro, or the New Milford as a whole where the Kingsley is absent, is composed of more or less cross-bedded, gray or greenish-gray flags, some quite massive. Lithologically, they resemble the Delaware River flags. The upper portion is cliff-forming. The maximum thickness is not far from White's figure and is between 400 and 500 feet in Susquehanna County, the region of its best development. Numerous excellent exposures are



Photograph by R. W. Stone

Figure 81. **Stone yard exploiting the new Milford flags, northeastern Pennsylvania.**

there to be had, chiefly in abandoned quarries, for the New Milford was locally the flagstone-producing member *par excellence* in the days when flagstones were in universal demand for sidewalks in the East. Now, with the use of concrete for that purpose, many quarries are abandoned and flagstones are in little demand for walks, but are used for ornamental floors in public buildings and for paving terraces, etc. White thought the New Milford was a fresh-water deposit, but Harding has found, during his years of search, marine invertebrates at intervals in at least the lower two-thirds. Plant remains are also common, but their preservation is poor. From a study of the stratigraphic sequence and of the fauna, supplemented by fossils and information collected by Harding and sent to Harrisburg,* it has been deduced that the New Milford consists of an alternation of marine and fresh-water beds. But for the fossils, this would not be apparent, for the lithology bears little proof of the environmental conditions under which the strata formed. At least, it appears that continental beds dominate at the top in the type region and pass over to marine westward.

The New Milford formation dives under the upper end of the Lackawanna syncline from the west, and fails to emerge as such on the eastern side. Rather, where it again comes to the surface, it is the Shohola formation already described. West of Susquehanna County, the marine increment increases, so that in central Bradford County the New Milford is all "Chemung" in lithology, that is, gray or olive-green, brown-weathering and rather soft sandstones and shales, all bearing marine fossils, usually in some abundance. Approximately the upper 100 feet of the New Milford is assigned to the Canadaway, the rest to the Chemung (Wellsburg and perhaps older). This statement is drawn from the paleontological data furnished by the Luthers Mills coquinite found to the west near the top of the New Milford formation, and from fossils which Harding and I obtained from Susquehanna County. The Chemung exposed along the Susquehanna River in northeastern Susquehanna County comes below the New Milford and is thought to be Cayuta. Nowhere are fossils particularly abundant in the eastern range of the New Milford, and preservation is usually poor. Pelecypods dominate. Therefore, the correlation is not based upon too firm a foundation. The Chemung-Canadaway line is not sharp, nor is there any clear separation of the Wellsburg from the Cayuta.

In northern Wyoming County on the railroad at Lemon and dubiously east thereof a short distance, but developed in increasing clarity to the west along the Susquehanna River, particularly at Lime Hill south of Wysox in Bradford County, is a bed of coquinite two to three feet thick. Not a true limestone throughout (there are limestone layers) most of it is a jumble of broken marine fossil shells. At Lemon it carries:

Camarotoechia contracta Hall
C. sappho Hall
Cryptonella eudora Hall
"*Spirifer*" *disjunctus* Sowerby

---

* Numerous letters and reports written by Mr. Harding are on file with the Pennsylvania Topographic and Geologic Survey, and I personally have spent some time with him in the field visiting most of his more important localities.

Productella lachrymosa var. *stigmata* Hall, too, occurs in the Susquehanna Valley in this bed. Such forms are also found at the bottom of the red Damascus. A similar fauna was listed from the Bradford County marine Honesdale. They are all closely allied to that of the Luthers Mills coquinite given below.

Williams and Kindle (265) named the Franklindale limestone found in Towanda Narrows near Franklindale on the south limb of the Towanda anticline as a substitution for the name "Burlington limestone" of Andrew Sherwood (189) which was preoccupied. Williams and Kindle believed their Franklindale to be the equal of the "Burlington" which was first described from an outcrop some miles farther north near Burlington on the north side of the Towanda anticline.

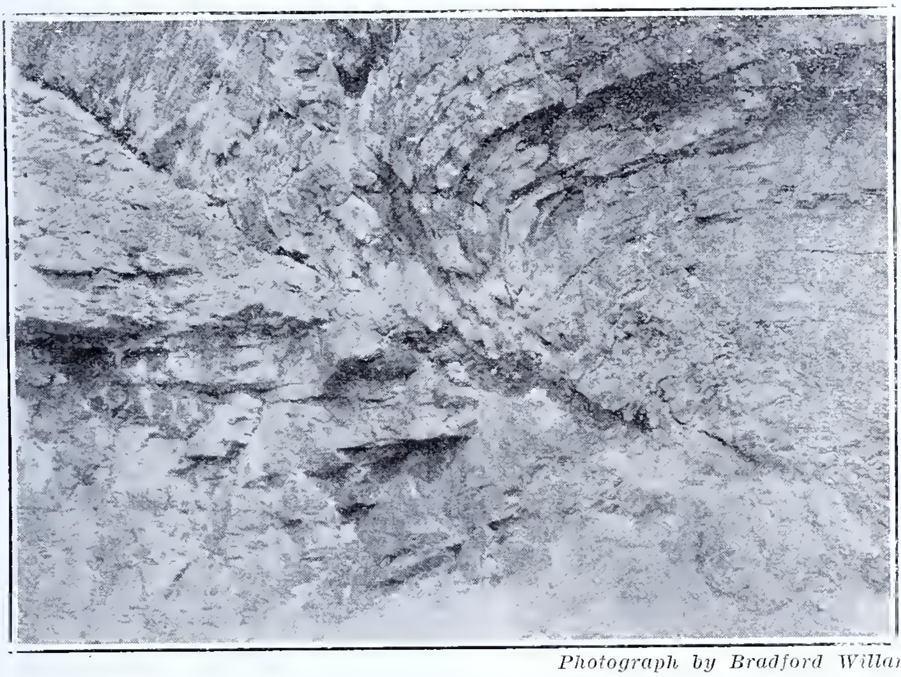
Sherwood's "Burlington limestone" at its type locality is a breccia of shells interspersed through a cement of red mud. This is the type locality for what I first called a coquinite (234), a name since applied rather widely in Pennsylvania. In central Bradford County near Burlington this is 40 feet thick. Presumably it is the correlative of thin beds of the same nature known near LeRaysville and Rome, many of which have been quarried and burned in this lime-poor area (147-8). Although sadly comminuted, several species of fossils have been identified from the coquinite near Burlington.

Productella lachrymosa var. *stigmata* Hall
Cryptonella eudora Hall
"*Spirifer*" *disjunctus* Sowerby

Also *Camarotœchia* and *Athyris* have been found, but were not specifically identifiable.

The Franklindale limestone of Williams and Kindle is, in contrast to the "Burlington," nearly a true limestone, *not* a coquinite. Also, it is older than the "Burlington" to the north, being probably late Chemung. Therefore, I believe that the Franklindale of Williams and Kindle is not the equivalent of what Sherwood called "Burlington". The type "Burlington" I consequently re-named the Luthers Mills coquinite (250) from a cross-roads east of Burlington. This coquinite, not the Franklindale, is correlated with the other coquinites to the east. Probably they are not continuous, but they are nearly contemporaneous and must have developed under nearly identical environmental conditions. In northeastern Bradford County, the Luthers Mills lies at the base of the lowest red beds atop the New Milford or in the highest New Milford strata. The position of the base of the Damascus red beds may vary slightly. Near Burlington it is a little lower, but it rises westward where the Honesdale and Damascus pass into the marine facies. Other marine beds may have been interpolated into the section under the Damascus and the Luthers Mills, or the former's marine equivalent may have considerably thickened westward. Assuming that the coquinites at Lemon, Lime Hill, LeRaysville, Rome, Burlington, etc., are essentially the same, they form a valuable key for the recognition of the upper part of the New Milford formation in this region and determine the age of this portion as Canadaway.

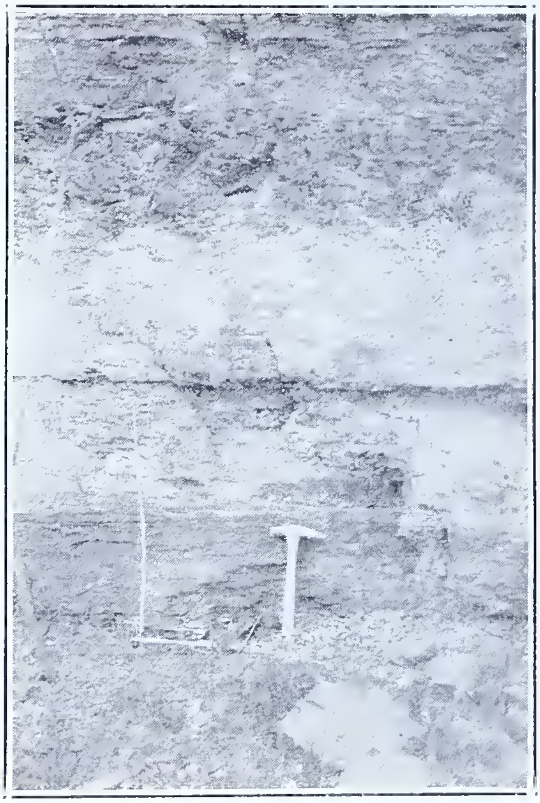
The New Milford in Susquehanna County rests upon marine Chemung correlated with the Cayuta and carrying no non-marine elements so far as ascertained. White (226) called this the "Starrucca olive shale", but there is no justification for the retention of this term. The Cayuta is the lowest formation exposed in northern Pennsylvania. Only down the Delaware Valley do older beds crop out. In that region White (226, etc.) mentioned what he termed the Lackawaxen conlgomerate, but I am not sure that this is a valid unit. Certainly, White's long range correlations between this local, continental bed and marine conglomerates in Huntingdon County are to be entirely discounted.



Photograph by Bradford Willard

Figure 82. **Wysox fault near Wysox, Bradford County, an expression of the type of structure here encountered.**

White (226) considered the red beds at the base of the New Milford which I have named the Kingsley shale to be the equivalent of the iron ores at Mansfield in eastern Tioga County. These ores and the Franklindale limestone have confused stratigraphers. Williams and Kindle (265) put the ores above the limestone. Sherwood (189) and Fuller and Alden (96, 97) considered them for the most part to be in the reverse order. The disagreement hinges on the mistake in identifying the Franklindale with the Luthers Mills ("Burlington"). The error was enhanced, probably, by an incomplete knowledge of the structural geology involved. Recent drilling and further field investigation by Cathcart and others show sharp folding and considerable faulting hitherto unknown. Claypole's brief account appears to have been forgotten (70). These structures roughly parallel the north side of Towanda Creek valley. Probably the Luthers Mills coquinite is not the same thing as the thin limestones of eastern Tioga County in the region of the development of the iron ores. Conversely, the ores disappear east of the Tioga-Bradford County line. Lacking thus a continuous key bed, the relations between the two regions are vague. The coquinite is relatively high in the marine beds, 300 feet below the base of the dominantly red portion of the column in central Bradford County. The base of the red strata there is lowest Cherry Ridge of early Conneaut or late Canadaway age. The ores, all save one, appear to be lower in section, some hundreds of feet beneath the base of the red beds. The older ores carry fossils assigned to the upper Chemung, below the lowest occurrence of *Athyris angelica*. The Franklindale limestone is also characterized by an upper Chemung fauna. Therefore, the Luthers Mills coquinite is placed higher than most of the Mansfield iron ores and the Franklindale limestone.



Photograph by Bradford Willard

***Figure 83.* Mansfield iron ore bed in abandoned pit near Mansfield, Tioga County. Hammer marks ore bed.**

White (226) thought that the Cascade sandstone, which he recognized in the lower Chemung in northeastern Susquehanna County, might equal the Fall Creek conglomerate previously described by Sherwood (189) from northern Bradford and Tioga counties. As the Fall Creek is now considered to be at the top of the Chemung, this correlation seems unlikely, nor is either the Fall Creek or the Cascade to be correlated with the Cuba sandstone as some think, for the Cuba is still higher, at the base of the Conneaut group. White placed the Fall Creek below the New Milford formation by 200 to 325 feet, an obvious error if the Fall Creek of White was the same as that of Sherwood. My field observations would place the Fall Creek below the Luthers Mills by perhaps 50 feet. If so, it should lie very near the contact between beds of highest Chemung and of lowest Canadaway age. What fossils I have seen from it indicate the former rather than the latter age.

ALLEGHENY FRONT CORRELATION

Although not final, pending completion of studies of the Mississippian by others, I have made some attempts to carry a correlation through from the Allegheny Front in Clinton and Lycoming counties

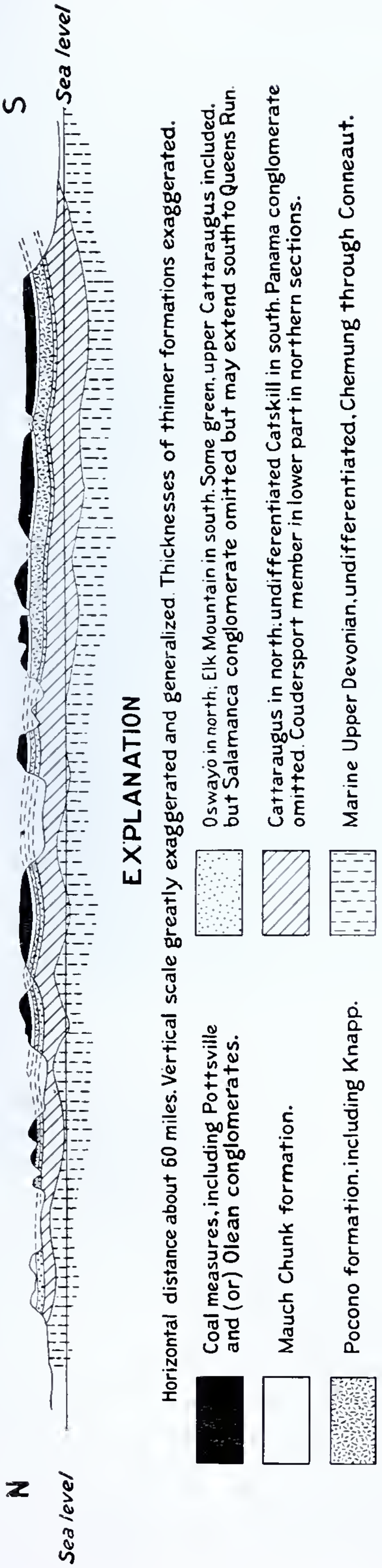

N
S
Sea level
Sea level
EXPLANATION
Horizontal distance about 60 miles. Vertical scale greatly exaggerated and generalized. Thicknesses of thinner formations exaggerated.
Coal measures, including Pottsville and (or) Olean conglomerates.
Mauch Chunk formation.
Pocono formation, including Knapp.
Oswayo in north; Elk Mountain in south. Some green, upper Cattaraugus included, but Salamanca conglomerate omitted but may extend south to Queens Run.
Cattaraugus in north; undifferentiated Catskill in south. Panama conglomerate omitted. Coudersport member in lower part in northern sections.
Marine Upper Devonian, undifferentiated, Chemung through Conneaut.

Figure 84. **Generalized section, northern Potter County to region of Lock Haven, illustrating Devonian-Mississippian relations in this part of Pennsylvania.**

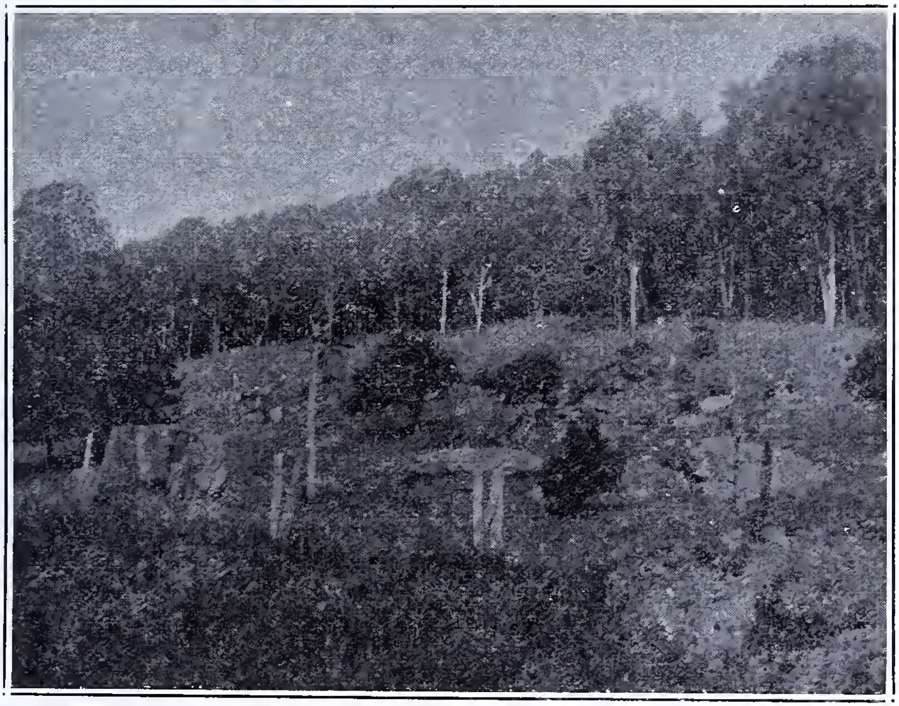
northwestward to McKean and Potter counties and to tie these in with Tioga County (250). It had been observed that the top of the Catskill facies along the Allegheny Front often carries an anomalous member composed of markedly cross-bedded, greenish, flaggy, rather coarse sandstone which in many respects strongly suggested the appearance of the Oswayo sandstone of north-central outcrops. It, and the beds on the Allegheny Front, are both barren. A reconnaissance was run down the Sinnemahoning and Susquehanna valleys through Cameron County to Lock Haven. Other sections were studied along Loyalsock, Lycoming and Pine Creek valleys. The results obtained substantiated the original suspicion of the equivalence of these similar beds. Furthermore, the Knapp flat-pebble conglomerate was thought to be found far enough south from the Warren-Bradford region to tie it in rather definitely with the lower part of the Pocono. However, flat-pebble conglomerates are deceptive and often repeat. Much was written about them by the Second Survey and subsequent writers. The general opinion seems to have prevailed and still does to some degree that round pebbles were formed in streams and the flat ones on coasts. The former were rolled by currents, the latter shuttled by waves. If this be so, here is an interesting correlary worthy of citing. The notably round-pebble conglomerates are the Olean or Pottsville and those of the Pocono, Honesdale, etc. These are admittedly continental in origin. The flat-pebble beds of the lowest Mississippian and highest Devonian measures of our northwestern counties are marine deposits. When I attempted to trace the flat-pebbled Knapp into the Pocono I found that there is a change from flat to round-pebble conglomerate. Such a change, coincident with the lateral transition from marine to fresh-water beds, is quite illuminating. At the same time that these observations on the Knapp and basal Pocono were made, a conglomerate believed to be the Woodcock-Tuna-Killbuck at or near the base of the Oswayo was found as far south as northern Cameron County, and may even extend down the Susquehanna to a point opposite Queens Run above Lock Haven. At that place it underlies beds of an Oswayo or Elk Mountain lithology. As a check on this, the Coudersport member is correlated with heavy beds in northern Lycoming and Clinton counties, but the Panama conglomerate (Wolf Creek?) was not surely recognized here.

Red beds persist and their thickness increases downward in the interval between the Coudersport sandstone and the Chemung proper. These were not differentiated, as nothing suggesting the Honesdale or other key units was found among them. Therefore, the red beds presumably are equivalent to the Cherry Ridge, Honesdale and Damascus, since they overlie upper marine Chemung at Lock Haven and underlie what I think is the correlate of the Oswayo or Elk Mountain. The red beds should also include the equivalent of the highest part of the Shohola and New Milford formations as well. As the Catskill thickens southward from McKean and Potter counties, the green, cross-bedded unit at the top is thought to maintain its place to the Allegheny Front. There it underlies the Pocono with no admitted representative of the Mount Pleasant red shale between (Figure 73).

The Second Survey members, particularly Chance (55, 56), Sheafer (188), Sherwood (190, 191), and Platt (157, 158), working in Potter, Cameron, Clinton and Lycoming counties attacked this problem of correlation. Chance made some interesting contributions; excellent, considering the handicaps under which he did his field work. He believed that the Pocono passed northwestward into shales which, in the lower part, became red and assumed a Catskill facies. He called what we know now as the Cattaraugus, the "red Pocono." He did not appreciate that the Pocono thinned out to the northwest with an essentially synchronous base throughout.

Summing up the Allegheny Front situation, I believe that the Pocono formation here is much like the Pocono of the east, though a little finer-grained, thinner-bedded and perhaps somewhat shalier. It rests upon beds of Elk Mountain or Oswayo lithology in rather sharp contact that is far from the traditional transition. These in turn may overlie a concretionary or conglomeritic zone thought to represent one of the higher conglomerates or the Roystone coquinite of the northwest. Under this zone comes in the red succession, the Cattaraugus plus, for a vast thickness at the "Front". The red sequence is not differentiated and can be correlated only nominally with that of the northeastern sections. Its base rests upon and interfingers with marine beds carrying an upper Chemung assemblage of fossils.

Farther east, particularly on the lower Susquehanna and Juniata valleys, the Pocono-Catskill relations differ from those of the Allegheny Front, typically Clinton County, due to the absence of the Oswayo or Elk Mountain, not found in the region next west and south-southwest of the Pocono Plateau. This distinction is noteworthy. Marine Pocono (Riddlesburg shale) is known in the Broad Top and adjacent sections of the Allegheny Front and south into Maryland. It may extend to the Susquehanna in Dauphin and Perry counties. It implies a less remote position from the ocean than the eastern, entirely non-marine Pocono. This supposition is supported by the finer grained, shalier or platier beds and thinner stratification. The Oswayo being Devonian in age, a thin remnant of the highest Devonian beds may therefore extend south through Lycoming County even as far as Bedford County where Oswayo-like strata occur beneath the Pocono. They apparently did not reach the lower Susquehanna Valley, where red beds may have supplanted the green, or they have been cut out by a Mississippian-Devonian unconformity. The Pocono of the Allegheny Front, with its diagnostic plants but nearly non-diagnostic marine faunules, is clearly Mississippian; the green beds below are quite surely Devonian. Probably they have been commonly mapped or considered as belonging to the Pocono, which may in part account for the assertion sometimes made that the lower part of the Pocono in southern Pennsylvania is perhaps of Devonian age or contains red beds.



Photograph by Bradford Willard

Figure 85. **Conglomerate (Knapp?) float west of Coudersport, Potter County.**

THE POCONO QUESTION

What is the Pocono, where is its type locality, what is its make up? These queries have been asked and answers suggested in recent discussions of the topic (10, 50, 100, 124, 168, 222, 225, etc.). It is necessary here to cite something of the literature and conceptions regarding the Pocono because of longstanding mistakes as to its nature in eastern Pennsylvania and recent confusion with the Devonian. These errors I have pointed out in attempts to correct them, but a summary of the situation must be here repeated. The type locality for the Pocono is usually taken to be the Pocono Plateau. This is only partly correct. In helping to prepare the first State geologic map, 1858, Lesley was responsible for the interpretations of the formations of the Pocono Plateau, and he it was who erred first in assigning a large part of its surface to the Vespertine or No. X which today we call Pocono. The Second Survey merely reëngraved this error. Lesley, dictator and autocrat of that body, perpetrated his incorrect concept in the face of the contrary and correct findings of I. C. White in Pike and Monroe counties (228). The whole difficulty was that what Lesley insisted was Pocono over a large part of the Pocono Plateau was actually the very similar Honesdale sandstone. White knew this, and Lesley admitted White's correction when he, Lesley, wrote the introduction to Volume G6 (228) but he never allowed the admission to go farther or appear as a correction on the county map. The Mississippian Pocono formation actually forms only the western rim of the Plateau and holds up the Moosic Mountains. The escarpment of the Plateau is the similar Honesdale sandstone. The surface of the Plateau consists of the younger, red Cherry Ridge and Mount Pleasant formations, the greenish Elk Mountain sandstone and part or all of the similar Honesdale. These lie nearly flat on the Plateau, but the dip increases southwestward toward the Lehigh, so that the formations occupy continually narrower bands until the Honesdale and Pocono closely converge in Bear Mountain and its continuation, Second Mountain below Mauch Chunk and westward. This is usually a double-crested ridge. The *northern crest* is the *true Pocono* of *Mississippian age* and is traceable into the western edge of the Plateau and the Moosic Mountains. The *southern crest* is the *Honesdale* and in part the *Pimple Hill* conglomerate. (It will be recalled that the Elk Mountain has dropped out.) Between the two crests are red beds of post-Honesdale but pre-Pocono age, that is, highest Devonian. The name Pocono should be retained in the literature, since this formation is represented by Mississippian beds along the western rim of the Pocono Plateau, but it must be distinctly separated from the Honesdale. This is shown in the map of the northeastern quarter of Pennsylvania which depicts the true relations of the Pocono and the Upper Devonian continental formations. (Figure 72.)*

SUMMARY

The following table shows thickness changes in the Catskill members in northern and northeastern Pennsylvania:

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* I recently published a fuller account of the Pocono question (250), but refrain from repeating it here as it is controversial and not particularly pertinent.

Table XXXI, Thickness changes of Catskill units

Formation	County or area								
	McKean	Potter	Tioga	Bradford	Susquehanna	Wyoming	Wayne County and Delaware Valley	Pocono Plateau	Brodhead Creek
Mt. Pleasant	0	10	0–10	10	475	345	596	400	350?
Elk Mountain or Oswayo	250	325	160	140	170	200	125	75	100?
Cherry Ridge or Cattaraugus	300	350	800–1000	800	400	465	500	275	375?
Honesdale				0–100	0–200	170	200	600	500
Damascus				0–175	125	160	400	510?	1500
Shohola							725	(?)	

This table shows that there is no great thickening of the Catskill eastward as some would lead us to suppose. Actually, the thickening is toward the southeast, not the east. Sections from Tioga to Perry and Schuylkill counties should show this to advantage had we sufficient subsurface data to draw them fully. Tabulating the thickness from the top of the Mount Pleasant to the bottom of the Honesdale we have:

	Feet
Bradford County	1050
Susquehanna County	1245
Wyoming County	1180
Wayne County & Delaware Valley	1421
Pocono Plateau	1350

To this, for comparison, we might add Perry County, 4500 feet, but here the base is of course somewhat older than the Honesdale, early Shohola, in fact. The post-Chemung is about 4,000 feet thick.

All but the highest Devonian unit of the continental Catskill facies may be traced into marine strata and directly correlated. This may be demonstrated by the Table XXXII, page 309.

I have described the Devonian-Mississippian relations in Pennsylvania, particularly between the continental representatives of these systems. The boundary appears to be disconformable. A transitional relation is probably exceptional, not, as formerly taught, the rule. The lithologic break among the continental beds is directly correlated with a faunal and lithologic break among the marine beds of our northwest.

I have shown that the Pocono does not occupy the major part of the surface of the Pocono Plateau. The formation is confined to the

Table XXXII, Correlation for Northeastern Pennsylvania

Formations	McKean County	Potter County	Tioga County	Bradford County	Susquehanna County	Wayne County	Monroe County	Perry County	Clinton County
MISSISSIPPIAN	Knapp	....	....	....	Pocono*	....	....	....	....
HIGHEST DEVONIAN DIVISION, UNNAMED	Absent, disc.	....	....	....	Mount Pleasant*	....	....	?	...absent
CONEWANGO	Oswayo* .... Cattaraugus*	....	....	....	Elk Mountain* .... Cherry Ridge*	....	....	absent..........	? ... Dk
CONNEAUT	Cuba	....	....	....	Cherry Ridge*	....	....	....	Dk
CANADAWAY				....	.... New Milford*..	Honesdale* .... Damascus* .... Shohola*	....	.... Dk	Dk Dk Dk
CHEMUNG					New Milford*.. Chemung	Shohola* .... Shohola*	?... ?....	[illegible] .... [illegible]	Dk Dch
PORTAGE						(concealed)	Delaware River* Analomink*	Trimmers. Rock	Dp

All formations continue completely across, except as noted, and pass westward (to the left) into their marine equivalents. The basal Cherry Ridge in Bradford County may be upper Canadaway.

Dch—undifferentiated Chemung
Dp —undifferentiated Portage
Dk —undifferentiated Catskill
* Partly or wholly continental

western edge of that topographic feature and the Moosic Mountains, the rest of the Plateau being floored by Devonian rocks.

I. C. White's Catskill divisions are in general valid, and little nomenclatorial change has been necessary in using them. My chief, adverse criticism of his work has been the matter of correlation, but his interpretation of the late Devonian continental sequence is to be highly commended and applauded. In my recent paper on the northeast I discussed the interpretation by Chadwick in which he brought forth the novel, but, as far as I can see, inapplicable and unsubstantiated concept that the Pocono is "white Catskill". We need not enter further into this discussion.

Summing up the correlations of the members of the Catskill continental facies with their marine equivalents generally we have:

Marine	*Continental*
Upper Conewango	Elk Mountain
Lower Conewango	Upper Cherry Ridge
Conneaut	Lower Cherry Ridge
Upper Canadaway	Honesdale
Middle Canadaway	Damascus
Lower Canadaway	Shohola (Paupack)
Chemung	Shohola (Barryville)
Upper Portage	Delaware River Analomink

CHAPTER IX

CORRELATION

METHODS OF CORRELATION

The sub-science of geology called stratigraphy may be defined as the "origin, history, sequence and correlation of bedded deposits of rocks". The ultimate aim of stratigraphy is correlation. By correlation is understood the matching of strata, that is, demonstrating which beds or formations in one section or region are the chronologic equals or correlates of certain beds or formations in another. Often, a newly studied section is correlated or compared with one long known. The latter may be then referred to as the standard or type section. There is but one sure way to correlate, that is actually to trace a particular bed or group of beds from a given locality to another. Often this is not feasible; perhaps erosion has cut out the sequence at some intermediate place, or at points the sequence is covered by younger rocks. In such cases other methods must be called into play. There are several ways and means of making correlations, but all may be classified according to whether they are based upon (a) the *inorganic character of the rock or lithology,* (b) the *organic (biologic) character of the rock or its paleontology,* and (c) a *combination of lithologic and paleontologic evidence.* In correlating, no specific, hard and fast rules can be quoted. In general, it is a case of applying all the information and experience available to the individual stratigrapher in a particular field.

Correlation by lithology.—Correlation may sometimes be carried out on purely lithologic data. Some sedimentary rocks are barren of fossils, or what fossils they contain may be non-diagnostic. Again, fossils if present at all may be very scarce. Metamorphism may have so damaged the remains that they are unrecognizable. In such cases lithology must be employed in correlation.

The general appearance of the rock is helpful in correlation. Certain persistent or key beds of peculiar lithologic aspect may be recognized. Color is a great factor—not only the color of the fresh rock itself, but that of its weathered product, the color it imparts to the soil above it, the color of its streak, that of the powdered rock, or its color when scratched. Changes in color of residual soils are also a key to variations of the underlying bedrock. In mountainous regions composed of folded sedimentary rocks, correlation may be effected provided certain lithologic types produce particular or peculiar topographic features, such as ridges, cuestas, hogbacks, benches, valleys, rows of sinks, drainage patterns, and the like. An accurate topographic map on a scale adequate to bring out the finer details of such an area is a vast help in this type of correlation. Closely associated with the use of topography is the recognition of such features as rows of springs trickling from a pervious layer along a valley side.

Minerals or mineral aggregates are applicable in lithologic correlation. Some beds may carry distinctive concretions, cone-in-cone structure, and specific minerals such as glauconite or pyrite. Insoluble residues obtained when calcareous sediments have been digested in dilute acid afford correlative data in that the character of the mineral residue or its percent composition varies among different formations or individual beds. In much the same light may be regarded the studies of the heavy mineral particles in sediments, a method applicable more to the non-calcareous, clastic rocks. Pseudofossils may be sparingly used, but in general, mud cracks, ripple marks, rain prints and the like are of local occurrence or confined to parts only of a chosen bed or group. Metamorphic and igneous phenomena have their application. Alteration of sediments affects dissimilar types differently. Unusual results are obtained, particularly in sorts of minerals and structures produced. Sills are known to follow bedding surfaces over wide areas, and as such have a correlative value often expressed topographically. Falls of volcanic ash can cover broad areas. When such a fall is buried, it may be altered to a distinctive layer of bentonite or metabentonite. As such it becomes one of the most nearly perfect key beds known to stratigraphy.

A highly refined lithologic means of correlation and one particularly applicable to subsurface work is that of matching sequences. Given a particular section or succession of four beds, each bed possessed of a distinctive character or characters, the discovery of a like sequence in an adjoining section is an almost infallible means of correlation because there is so little mathematical probability of the chosen four being duplicated by an earlier or later sequence. By a similar process it may sometimes be ascertained that a particular unit present at one place is absent elsewhere. The recognition of disconformities, unconformities or diastems serves as a valuable check upon correlation. The relative position of a particular bed as referred to adjacent strata is often a help in determining its age and correlation. In this respect, carefully measured thicknesses and intervals are an adjunct, provided of course that one is reasonably certain that there is comparatively little or at least a constant variation in thickness or interval.

Finally, of all inorganic correlations, the most significant is the recognition of contemporaneously formed lithologic facies. The far reaching value of this concept cannot be overemphasized. Determine which limestone, shale or sandstone or parts of such formed simultaneously with one another, and half the game of strata matching is won. While this method may lack refinement, in that lesser details must be supplied by closer attention to other means of correlation, it is nevertheless a concept which must be constantly applied.

Correlation by paleontology.—In many respects correlation by fossils or applied paleontology is not so very different from correlation by lithology. The basic principles are much alike in both. Fossils may be looked upon as labels attached to the strata. Paleontologic correlation draws its major premise from the concept that today in fairly contiguous regions where physical conditions are alike, closely similar plants and animals should be living. If this is true of living forms today, it ought to hold good for ancient conditions. In general, this premise is valid, but too much is now and again taken for granted and again too little attention paid to contemporaneous facies. Observations of minute varieties of organic forms are probably of less correlative value than careful distinction of facies changes.

A basic unit for organic correlation is the index or guide fossil. Certain fossils are believed to be confined to particular geologic units. As such they are recognized guides or indices to the particular bed or beds in which they are found. The concept is applicable, but unless due account be taken of slow, lateral migration and facies distribution, error results. Obviously, those forms with a great geographic distribution and simultaneously, highly circumscribed geologic range, are most ideally qualified for guide fossils. As a corollary, it is observable as a paleontologic axiom that the simpler, more generalized types, have the greater geologic range. Conversely, and equally axiomatic, the short-lived forms are the more highly specialized, distinctive forms. But guide fossils are often of little value or are actually non-existant. Even though well established in one area, their significance may break down in an adjacent field of operation where their ranges are found to be dissimilar to those which they possessed in the first or type locality.

Correlation can sometimes be accomplished by groups of fossils or entire faunas examined as a whole. We are familiar with the types of plants and animals which, in a general way, characterize the life dominant during any of the larger divisions of earth history. In a more precise manner, many of the smaller, chronologic units of geologic time were peopled by definite biotas or simply faunal or floral associates. Some of the members of such an association are found to have lived during older or younger times, but a particular grouping, peculiar to a given time interval or stratigraphic unit, establishes a definite level of correlative value. Thus, in our standard sections, we can often designate faunal assemblages which alone characterize each particular unit. In working out the sequences and correlations of a new field, one must often establish afresh his own faunal groupings. With abundant collections from each unit, such groups can be established. A similar method is the recognition of faunal zones composed usually of one or a few associated fossils occurring at a definite level over wide areas. Provided there is no repetition, this type of correlation is relatively reliable.

Correlation between contemporaneous but different facies is often important, but usually difficult to determine. If the facies are not too widely divergent, their faunas may be compared on a percentage of similarity basis. So may estimation of equivalence be deduced. In adjacent facies, characteristic fossils of one fauna may temporarily invade the other as a brief shift of facies takes place.

The stage of organic evolution attained by plants and animals found fossil is applicable in correlation. Given a series of closely consanguineous organisms taken from a succession of beds; if these belong to a mobile group which was undergoing steady evolutionary progress, each succeeding stratum or group of strata may be expected to yield fossils representing a precise evolutionary stage. The discovery of the same precise stage of evolution in another region is presumptive evidence for correlation, because organic evolution is neither reversible nor does it repeat itself.

Throughout, in using paleontologic data for correlation, environment and facies development must be constantly kept in cognizance. Take the problem of marine correlations; the remains of benthonic forms, bottom-dwellers, crawlers, burrowers in the mud and sand, and sessile forms usually are buried and preserved in the medium in which they spend their lives. As such they may become good facies guides though sometimes of restricted geographic range. Pelagic and nektonic forms on the other hand, when they die, sink to the bottom to be buried in a medium quite certainly totally unrelated to the environment in which they lived. As such, they tell little of the local facies, but through their wide distribution may cover a relatively vast geographic range, transcend the boundaries of lithic facies, and serve as one of the finest types of long range correlation by fossils. In a continental environment, a counterpart of the foregoing proposition is found in wandering or migratory animals as contrasted with home-loving forms, and in those plants whose seeds or spores are readily transported far and widely disseminated, in contradistinction to those devoid of such well-developed means of distribution.

Correlation through a combination of inorganic and biologic factors is of course the best means at our disposal. Each method forms a check upon the other; they mutually support each other's evidence. When a lithologic sequence of four strata has been selected for comparison, if a paleontologic check may be obtained by noting their characteristic and distinctive fossils, we "make assurance doubly sure".

DEVONIAN CORRELATIONS IN PENNSYLVANIA

Correlation of most of our Devonian units in Pennsylvania has already been described by individual groups. I have demonstrated how the passage of the Catskill continental facies into marine beds establishes the relative ages of the fresh-water-formed beds. This demonstration depends entirely upon principles of correlation, both organic and inorganic. In many sections of the Catskill, correlation by lithic sequences on a large scale through recognition of alternating red and gray divisions was worked out.

By observing the earliest appearance of the distinctive fossil, *"Spirifer" disjunctus,* the base of the Chemung is determined. Lithology and paleontology have served to differentiate the Chemung, Canadaway, Conneaut and Conewango. In the northwestern area, the Cuba conglomerate and the Panama conglomerate respectively mark the bases of the Conneaut and Conewango. The Dunkirk black shale punctuates the beginning of the Canadaway. But these alone cannot be relied upon unsupported. Other conglomerates are present, and sandstones too which may confuse the issue. Rather, the associated fossils characteristic of each group must be determined. Then, the different lithologic sequences of the several units of the groups form a final check. But because of shifting facies, limited areal distribution of stratigraphic units, and an incomplete faunal check, correlation in northwestern Pennsylvania is still open to correction and revision. Parenthetically, the Devonian-Mississippian disconformity is applicable here and eastward in correlating the top of the marine with that of the fresh-water Devonian beds.

The Portage with its contemporaneously deposited, complementary shale and sandstone facies illustrates well the problem of correlating between two such unlike bodies of simultaneously-formed strata, strata not only lithologically different, but faunally distinct. Temporary facies shifts here tie together these unlike parts of a great group. Furthermore, the Losh Run shale is essentially a faunal zone characterized by an abundance of *Reticularia laevis.* Its presence at or near the base of the Trimmers Rock and the Brallier proves a valuable datum for matching dissimilar phases of sedimentation. I have described our Tully and Burket. Used separately or collectively, they are key beds of distinctive lithology. As such, coupled with their faunas, particularly that of the limestone, they are of high correlative value and serve to separate the Hamilton group from the Portage. In the restriction of *Hypothyridina venustula* to the Tully we have an example of what appears to be, here at least, a true index fossil. Hamilton correlations are largely based upon faunal assemblages. Though sharp lines can seldom be drawn between beds of Moscow, Ludlowville, Skaneateles and Marcellus ages, these four may be distinguished by their faunal assemblages. Certain species are more abundant in one than another. Thus, the Ludlowville with its many pelecypods shows a distinct dominance of one class of invertebrates. The thin sandstones of the Mahantango, though hardly facies, are characterized by a few relatively large brachiopods and snails found but sparingly in the more shaly beds. The Montebello is distinguished purely on its lithology from the rest of the Mahantango. Curiously, its faunas are no different from the rest of the Hamilton group in general. Locally, the Marcellus is concretionary; sometimes it has thin, limestone interbeds. These features may serve to tell it from the Burket. Faunal zones have proved of little use in the Middle and Upper Devonian correlations in Pennsylvania, but the Hamilton group is exceptional in this respect. At its top in most sections a zone of *Vitulina pustulosa* with or without "*Spirifer*" *tullius* is recognized. At or near the base of the Ludlowville faunal facies the Centerfield coral reef is a prominent zone in Monroe County and other eastern parts. A storm roller zone not uncommonly overlies this zone by a brief interval.

The Onondaga group is usually identified on two criteria. Limestone is present in its upper part nearly everywhere save in some south-central sections, and the ubiquitous *Anoplotheca acutiplicata* serves to identify the group paleontologically. The Tully, Onondaga and Helderberg are the three limestones one may look for in our Devonian sections. All have been mutually confused at one time or another, but each contains distinguishing faunal elements by which it may be differentiated from the rest. The Oriskany is commonly "spotted" by its lithology. Usually it contains a more or less prominent amount of the coarse Ridgeley sandstone. However, this citerion is not rigid, for only recently a similar sandstone in the Lehigh Valley has turned out to be of Esopus age, and the Montebello, Turkey Ridge and Mexico sandstones of the Hamilton group can be lithologically very like this sandy Oriskany. The distinctive faunal elements of the Oriskany must be used in corroboration of lithologic data. Much the same remarks apply to the cherty phase, the Shriver formation, as to the sandy Ridgeley. Here again, without the application of paleontology, the lower Oriskany chert has been confused with cherts of later Oriskany, Esopus, and of New Scotland ages.

In the Helderberg group perhaps more than in any other part of the Devonian, fossils are the chief basis for correlation. The sequence of limestones, limy shales and shaly limestones could never have been properly analyzed into its component parts and the correlation of these parts determined across the State were it not for their characteristic fossils. In the Helderberg, zoning of the fossils has proved applicable to a greater degree than is usual in the higher Devonian. Considering the Devonian as a whole, the chart presented in Figures 93, 65, 40, 36, 29, 17, serve to show the major problems of correlation.

In Figures 87, 88, 90 and 91 are shown fifteen transverse sections. The location of each is indicated in the appended key map Figure 86. It will be observed that each section covers practically the entire Devonian sequence, for they have been selected in regions where it is usually possible to begin with the Helderberg and continue into or through the Catskill. Incomplete sections are therefore eliminated as far as practicable. Such sections, for example, as those dealing with the Catskill facies in northeastern and north-central counties are to be found in their appropriate place in Chapter VIII. Likewise, in the foregoing chapters will be found details of correlation of groups or lesser units that could not be preserved here in a general review.

The transverse sections are drawn in each case as nearly as possible perpendicular to the strike. A certain degree of generalization could hardly be avoided in the relatively small scale necessarily employed. A vertical exaggeration of thrice the horizontal scale was adopted as best fitting the entire group of sections. Some details have been omitted, such as most of the divisions of the Catskill, minor Portage elements, the Hamilton faunal facies, and the integral parts of the Helderberg. Major structures are shown, but minor flexures and faults are omitted. A strict adherence to thicknesses could not be followed, since certain important units had to be shown which, if drawn to scale, would have become microscopic in the figures.

The fifteen sections are grouped in two series. Sections 1-7 comprise the first or eastern series; sections 8-15 make up the second or northern series. The eastern series commences with a section in southeastern Monroe County and continues along the valley between Kittatinny and Second Mountain or its equivalent, to the lower Susquehanna Valley. As a continuation westward a section in the lower Juniata Valley is added. The northern series is principally of sections obtained at or near the Allegheny Front. Beginning in east-central Bedford County, these sections follow the curve of the Front and the mountain arcs north and northeast into Lycoming County. Two sections to the southeast show conditions in the Susquehanna Valley at the forks and in Columbia County. These last are more or less intermediate between the eastern and northern series.

Eastern Series

Section 1, Brodhead Creek.—The easternmost section of the eastern series is the Brodhead Creek section. This lies in southeastern Monroe County. Beginning at Godfrey Ridge due south of Stroudsburg, it runs north through that town and so up the valley of Brodhead Creek to the village of Analomink. Godfrey Ridge itself presents some interesting problems. South of Stroudsburg the section shows it to be an anticline capped by the Esopus sandy shale. The south slope of this ridge is steeper than the dip of the underlying beds, so that from the bottom up the Helderberg, Oriskany and Esopus successively crop out. The highly sheared Esopus is exposed across the top and dips suddenly down at the north side, only to rise again in

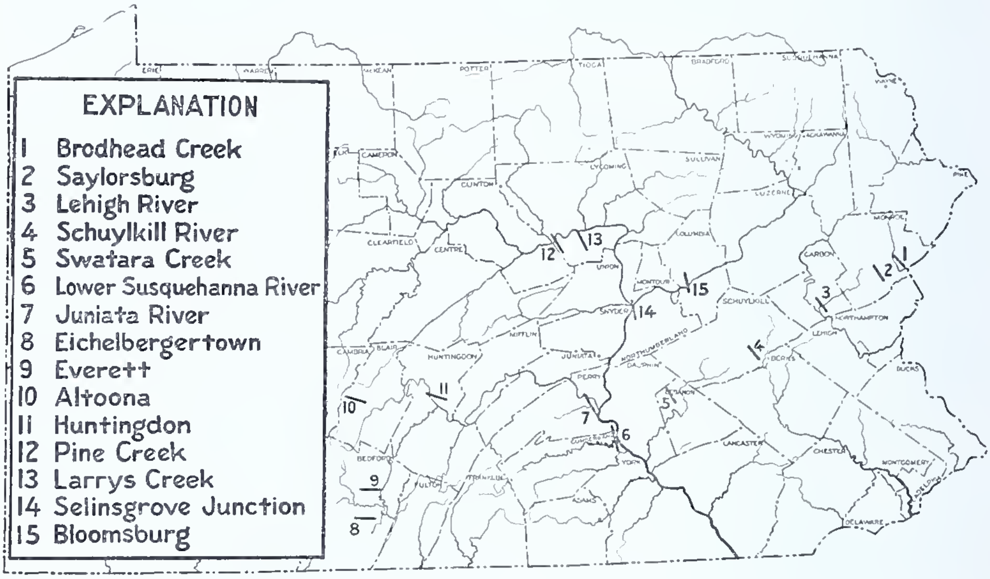

Figure 86. Key map showing locations of geologic cross-sections depicted in Figures 87, 88, 90, and 91.

KEY TO SYMBOLS IN CROSS SECTIONS. FIGURES 87, 88, 90 AND 91.

Trd=Triassic diabase
Ppv=Pottsville
Mmc=Mauch Chunk
Mp=Pocono
Dk=undifferentiated Catskill
Dkcr=Cherry Ridge
Dkh=Honesdale
Dkd=Damascus
Dkdr=Delaware River
Dka=Analomink
Dch=Chemung
Dp=undifferentiated Portage
Dpph=Parkhead
Dptr=Trimmers Rock
Dpbr=Brallier
Dplr=Losh Run

Dphl=Harrell
Dpbk=Burket
Dpl=Laurens
Dt=Tully
Dh=undifferentiated Hamilton
Dhmt=Mahantango
Dhmb=Montebello
Dm=Marcellus
Don=Onondaga
De=Esopus
Do=Oriskany
Dhb=Helderberg
S=undifferentiated Silurian
Sbv=Bossardsville
Ston=Tonoloway
Sb=Bloomsburg

a small syncline in which rests a slice of Onondaga (Buttermilk Falls) cherty limestone. Folds of less amplitude follow, but subside northward. The Onondaga-Marcellus transition has been seen on McMichaels Creek in Stroudsburg. A fairly uniform, gentle dip carries the succeeding Hamilton and Portage units under ground northward until the Analomink red shale and succeeding Delaware River flags are encountered about Analomink, at which point the section ends. Significant points are the thick Esopus and Buttermilk Falls formations (here a maximum for the State), the exceptionally thick Marcellus, and the nearly undifferentiated marine Portage. The Centerfield coral reef is here a prominent feature of the Hamilton group, and shows well in the Brodhead Creek section. Lithologically, the Portage is similar sandstone throughout, but at its base the Laurens with *Hypothyridina venustula* is faunally identified. More than one-half of the beds of Portage age belong to the Catskill continental facies.

The structure of Godfrey Ridge should be further noted. Only a mile or two east of the figured section, Brodhead Creek as it turns south into the Delaware has cut across the ridge in a miniature water gap. Along the west bank of the creek the anticlinal structure of the ridge may be observed. Directly across the creek in a succession of cuts on the Erie (formerly the New York, Susquehanna and Western) Railroad, these beds are in regular sequence and all dip steeply north. Apparently the gap of Brodhead Creek follows a tear fault. West of it the strata are up-arched; east of it they are merely tilted steeply north. As sections farther west are described, the structures encountered along Godfrey Ridge or corresponding ridges will be noted. Apparently there is in this portion of the sections a band or zone of dislocation from the Delaware to the Susquehanna.

Section 2, Saylorsburg.—Section 2 lies in south-central Monroe County. It commences on Chestnut Ridge, the western continuation, topographically, of Godfrey Ridge, and runs north past Saylorsburg, crosses the eastern end of Wier Mountain, then is off-set to the west beyond Brodheadsville, and runs on north again through Effort to the crest of the Pocono Plateau, here called Pohopoco Mountain. Chestnut Ridge is of surprisingly different stratigraphic constitution from Godfrey in Section 1. Along its south slope the Upper Silurian Tonoloway or Bossardsville ("ribbon") limestone is exposed in abandoned quarries. The top of the ridge is relatively broad and flat, and near the south edge of the crest adjacent to the more or less crumpled limestone, an ancient, abandoned iron pit shows the presence of the Oriskany. Clearly, the Tonoloway is up-thrust against this sandstone, and the Helderberg is cut out. An Oriskany-like sandstone forms the northern edge of the crest. This is taken to be a representative of the Bowmanstown and Palmerton cherts and sandstones found to the west and occupying part of the Esopus. These beds have often been confused with the Oriskany, and their true identity has only recently been demonstrated. A sandstone in a railroad cut south of Saylorsburg and on the strike of this ridge is supposed to be the same. There, its Oriskany-like nature is apparent, but its barrenness is eloquent, though negative evidence for its correlation with the higher beds.

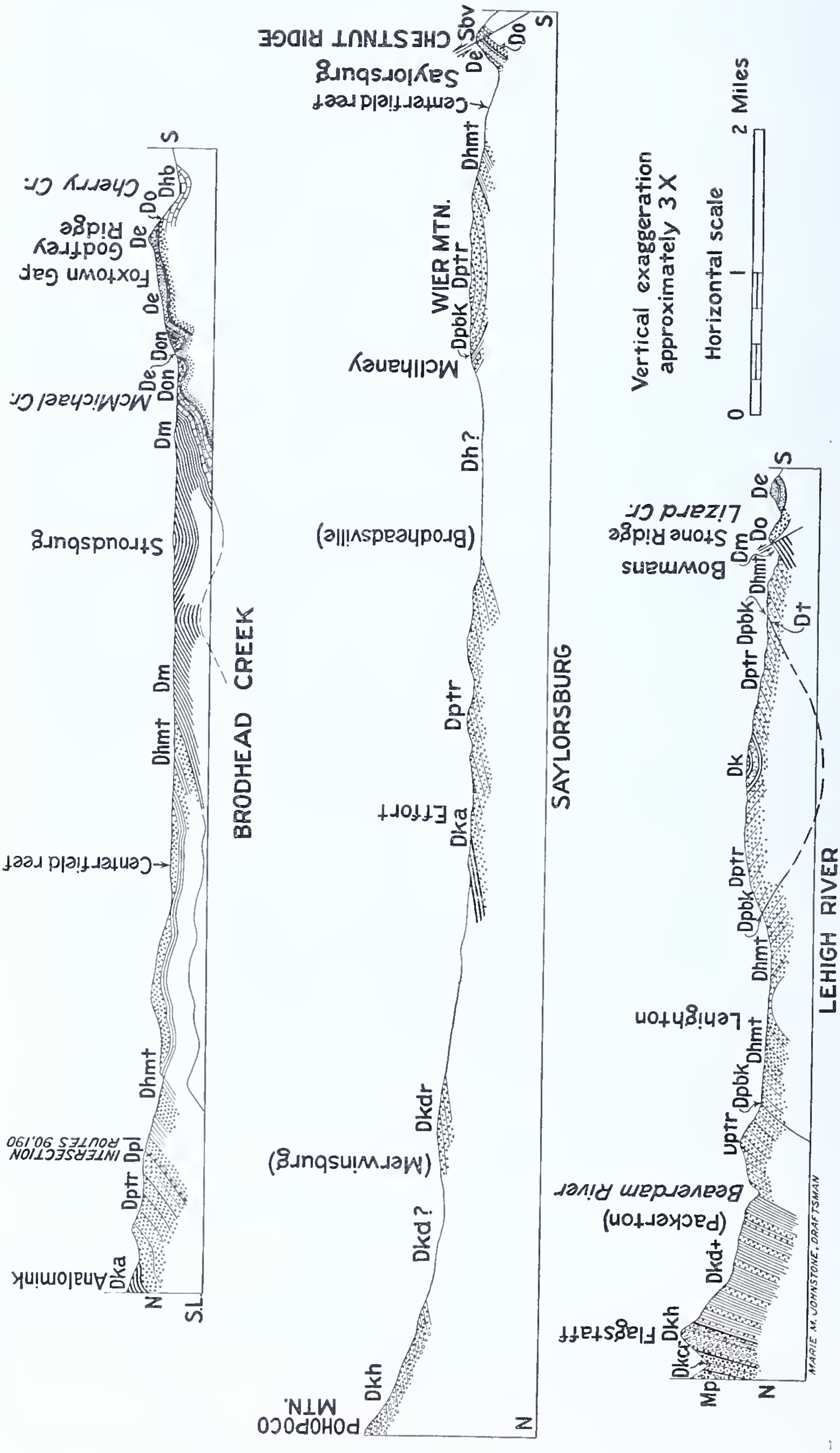

Figure 87. Geologic cross sections, generalized, vertical scale exaggerated, on Brodhead Creek, at Saylorsburg, along Lehigh River. See Figure 86 for key to localities and symbols.

Unconsolidated sediments occupy the valley north from Saylorsburg, but Wier Mountain syncline shows many exposures. Correlation with the Hamilton in Section 1 is effected by the exceptionally fine development of the Centerfield coral reef on the south limb of this fold. In this section differentiation of the Portage goes a step farther than to the east. The Burket black shale now overlies the *Vitulina* zone at the top of the Hamilton. Laurens or Tully, I have not certainly found here, but a sparce Naples fauna in the shale above the Burket indicates perhaps a trace of Harrell shale. The Trimmers Rock sandstone fills in the rest of the syncline in Section 2, but at this point the fold is of insufficient depth to embrace the Catskill, albeit the red beds are encountered on the crest of Wier Mountain westward toward the Carbon County line.

South of Effort the Trimmers Rock again comes down, and its fossiliferous beds continue north beyond the town, where a red zone is correlated with the Analomink. Here, the Portage sandstones above this red band show some marine fossils, indicating a westward transition from continental to salt-water facies. In this section the sequence includes higher beds than Section 1 and so includes the massive, gray Honesdale sandstone of late Devonian age and Catskill facies which here supports the lip of the Pocono Plateau.

Section 3, Lehigh River.—Along the Lehigh River from a point opposite (west of) Palmerton, north through Lehighton and Packerton to the crest of Mauch Chunk Ridge south of the town of Mauch Chunk, Section 3 has been drawn. Two small sandstone ridgs rise at its southern end, and between them Lizard Creek runs east into the Lehigh. The southern ridge is a somewhat distorted syncline composed chiefly of sandstones which I consider to be of Esopus age with perhaps some Oriskany at the bottom. These sandstones are the Palmerton and Bowmanstown members recently recognized and described from this region by Swartz and Swartz. The underlying Oriskany rises in Stone Ridge, the ridge north of Lizard Creek, and there produces a characteristic "rock city." It dips steeply south, and, at its northern base on the Lehigh Valley Railroad, is faulted against fossiliferous Marcellus black shale.

This Lehigh Valley section embraces the region of the Onondaga paint ore, but the ore is not shown to advantage in the chosen section as drawn west of the river. In a still more structurally complex section north from Palmerton through Stony Ridge east of the river, the Onondaga paint ore overlies the sandstones of Esopus age. Intermediate stations between Sections 2 and 3, particularly in the vicinity of Little Gap and Kunkletown, show complex structures along this belt of Lower and lower Middle Devonian strata. Both folding and faulting obtain, and the faulting cuts out now one and now another unit.

The syncline that produces Wier Mountain to the east, continues across the Lehigh between Bowmanstown and Lehighton and there underlies a belt referred to as the Mahoning Hills. It is of sufficient depth to bring down the lower red beds of the Catskill. In the section across this structure the upper Hamilton-lower Portage relations are determined by a few feet of Tully limestone north of Bowmanstown, and there are a few feet of barren, dark shale correlated with the Burket on lithology and relative position alone. The Centerfield reef is again encountered, but inferiorly developed, on the north flank of the fold. Here and north of Lehighton the Trimmers Rock-Delaware River sequence is exposed. The Analomink has not been recognized, but measurements of thickness indicate that a still larger proportion of the continental beds of Portage age has gone over into the marine facies, while the total thickness of the Portage is slightly less than in Monroe County.

In the northern end of Section 3 are illustrated the Honesdale-Pocono relations. In Mauch Chunk Ridge, the mountain south of Mauch Chunk which westward is called Second Mountain, the strata stand nearly vertical. This mountain is double-crested. The section shows how the northern crest is Pocono-supported, the southern upheld by the Honesdale. Red beds intervene. Projecting the Honesdale east across the river along its strike, it can thence be traced along the edge of the Pocono Plateau for many miles. Not only can its correlation be established upon topographic evidence, but the rock itself makes a nearly continuous outcrop, often as bold cliffs along the escarpment. The double-crested feature of Mauch Chunk Ridge is observable westward in Second Mountain clear to the Susquehanna Valley, and is an important means of correlating the Honesdale and associated Catskill units, notably the overlying Pimple Hill or related reddish conglomerates.

Section 4, Schuylkill Valley.—The fourth transverse section of the eastern series has been drawn in the Schuylkill Valley. This section commences in a small ridge beyond the valley of Bear Creek south from Auburn and runs north via Landingville and Schuylkill Haven to the river and then up stream through Second Mountain to Sharp Mountain south of Pottsville.

The lowest beds at the south end are sandstone called Oriskany, but possibly including some assignable to the Esopus. Moreover, when these beds again crop out to the north, there is sandstone betwixt the Oriskany and the Onondaga (Selingsgrove) limestone. In Bear Creek valley, the Onondaga and Marcellus are concealed. In fact, the next beds exposed above the Oriskany are the middle Mahantango. These are highly fossiliferous and probably are to be classed as Ludlowville. The Centerfield is doubtfully recognized. A *Vitulina pustulosa* zone tops the Hamilton in this section, and is succeeded by shaly beds with Tully fossils and these by Burket black shale. The remaining Portage here appears to be entirely Trimmers Rock and is followed by Catskill red beds whose base should be very early Chemung or latest Portage. Additional Tully found in Schuylkill County is west of this section. The Devonian sequence is well exposed in the eastern end of Swatara Hill syncline which pinches out eastward near Landingville.

Schuylkill Haven partly occupies the western end of a northward-overturned anticline which brings up the red Silurian shales (Bloomsburg). South of the town the Helderburg, Oriskany, Esopus, Onondaga and Marcellus are all exposed and appear to be quite normal except that the Helderberg is thin. This thinning is interesting in consideration of the total absence of the Helderberg farther west. Here as in all sections to the east the Oriskany consists only of Ridgeley sandstone. Although cherty strata may be found among these sands, the fauna is strictly Ridgeley, according to Cleaves, and so excludes all possibility of the presence of true Shriver. The Esopus, be it observed, is here essentially the gritty shale of southeastern Monroe County, and the Onondaga limestone is now clearly the non-cherty Selinsgrove formation rather than the cherty Buttermilk Falls limestone of extreme eastern exposures.

North from Cressona along the Reading Railway the Portage sandstone passes into Catskill red beds with no trace of Chemung. The markedly double-crested top of Second Mountain shows, even better than in Section 3 below Mauch Chunk, the dual topographic expression of the Pocono and Honesdale. In this section, for comparison, the sequence has been run through to the Pottsville conglomerate of Sharp Mountain, so including the Mauch Chunk red shales which underlie the valley of Tumbling Run.

Section 5, Swatara Creek.—Starting on the north flank of Kittatinny Mountain in line of strike of the valley between that ridge and Swope Mountain to the north, a section was constructed north along Swatara Creek through Green Point. Here the stream valley turns abruptly east, but the section continues north across Second Mountain.

In this section all the beds are overturned north so that the dip is steeply south. The section is free of important folds, and so is relatively short. At the base, to the south, a little Selinsgrove limestone overlies a barren sandstone that overlies the Bloomsburg red shale of the Silurian with no trace of the Upper Silurian Tonoloway limestone between them. The identity of the Onondaga limestone is established on lithology, fauna and stratigraphic position directly beneath fossiliferous Marcellus black shale. That of the sandstone is in doubt. Lithologically, it suggests the Oriskany. Indeed, when I first studied this section I assumed it to be that sandstone, but subsequent observations have changed my interpretation. Cleaves, too, reports adversely upon such a designation. As the sandstone appears to be conformable with the Onondaga limestone, the presumption based upon elimination of other probable correlations is that this is either the Esopus or a stray bed in the uppermost Silurian. It is rather greenish, and it will be recalled that the sandstones of the Esopus at the Lehigh are not positively recognized west of the Schuylkill. Swartz and Swartz believed this sandstone to be Silurian,* but the evidence seems to be negative to whichever system it be assigned. Neither here nor in the neighborhood have either Oriskany or Helderberg been found, so that a fault is postulated beneath the sandstone if it is Esopus, above it if it be Silurian in age. Nevertheless, the possibility of an unconformity here is important, and cannot be denied. This relationship has been discussed in describing the Hamilton group on the Susquehanna, particularly at Rockville.

In our sections to the east, the Hamilton group is largely shale and sandy shale, and so produces no prominent topographic heights.

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* Geol. Soc. Am. Bull., Vol. 42, 1931, P. 635.

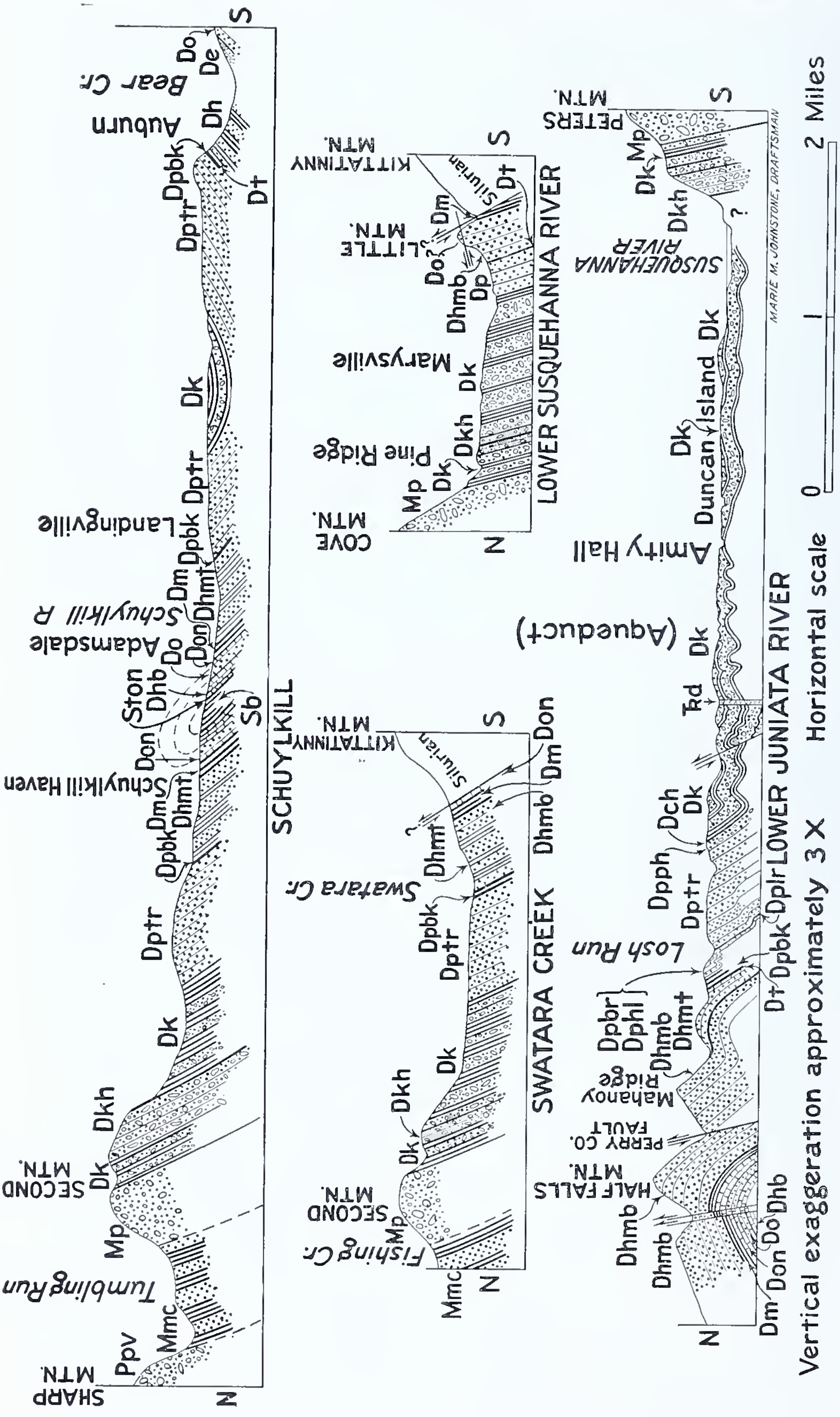


Figure 88. Geologic cross sections, generalized, vertical scale exaggerated, on Schuylkill River, Swatara Creek, lower Susquehanna and lower Juniata Rivers. See Figure 86 for key to localities and symbols.

But Swope Mountain is a sharp little ridge composed of beds of Mahantango age. Herein is the easternmost topographic expression of the Montebello sandstone which near here begins to displace the shales of the upper Hamilton of post-Marcellus age. We shall see that its prominence grows westward. Swope Mountain is the eastern continuation of Little Mountain, which, at Rockville, consists entirely of the Montebello sandstone facies.

Little more need be mentioned of Section 5 except to point out that, owing to thinning of the Honesdale, the southern crest of Second Mountain has dwindled proportionately. With the Honesdale gray or greenish beds are associated slightly younger, reddish conglomerates. These together produce this ridge remnant. Still, no Chemung fossils have been found above the marine Portage.

Section 6, Lower Susquehanna River.—Along the lower Susquehanna River north of Harrisburg, a good Devonian section is exposed. The figure illustrates this as if drawn along the west bank from the flank of Kittatinny Mountain north through Marysville to Second Mountain. Actually, it has been somewhat supplemented by data from the east side, particularly about Rockville. Like Section 5, there are no prominent folds, so that the over-all length is reduced, compared to some of the eastern sections.

In the valley separating Kittatinny from Little Mountain, the Bloomsburg red shale of the Silurian and the black Marcellus shale are exposed, almost in contact. This relationship has been discussed fully. In the figure a hypothetical fault is introduced. Little Mountain across central Dauphin and southeastern Perry County is the topographic expression of the Montebello sandstone and serves to trace it east and west. Key beds or faunal zones are none too clear in this coarsely sandy Hamilton, but the succeeding thin shale of Moscow age carries a *Vitulina pustulosa* zone at its top. About 50 feet of shale of Tully age overlies the Hamilton. The Portage is curiously thin. For such an anomylous condition, when contrasted with the same group fifteen miles north, an explanation has been suggested. Considering that the beds in this section are overturned north but have suffered little folding and that because of this attitude the massive Montebello sandstone has come to overlie the less massive Portage, it is not improbable that faulting, obscured in the relatively poor Portage exposures, has reduced the thickness of the group. Burket, Braillier and Trimmers Rock are present.

This is the westernmost section from which the Chemung is excluded and absent. The Honesdale is now reduced to a few feet of greenish sandstone which is the chief underlying cause of Pine Ridge, a small hill concentric to Cove Mountain, itself formed in Pocono sandstone north of Marysville.

Section 7, Lower Juniata River.—Along the lower Juniata River, starting in fact on the Susquehanna a mile or so below its confluence with the Juniata, and proceeding up the Juniata to its water gap through Half Falls Mountain, is the finest Devonian section in Pennsylvania. This has been discussed by Cleaves and me (258) in much more detail than can be here devoted to it, and the reader is referred to our Bulletin on this topic for more information on this section than can be given now. The following summary is based upon that Bulletin.

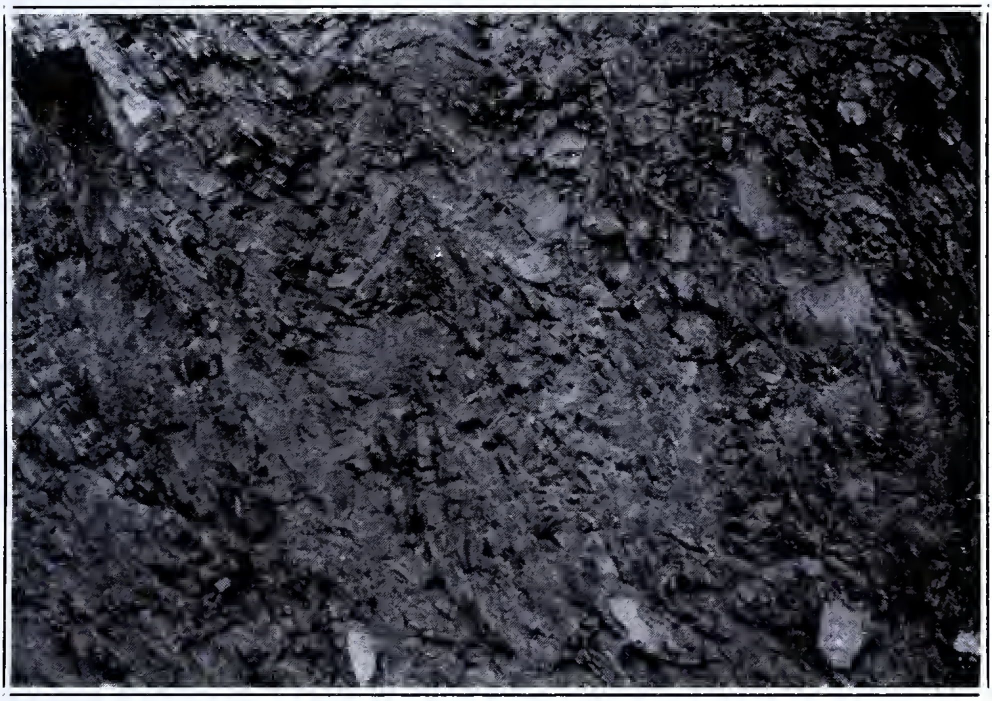
In order to conform to the description of foregoing sections to the east, which start with the oldest beds to the south, I shall begin the description of Section 7 from the north because there the oldest beds reach the surface.

Half Falls Mountain is an anticlinal ridge which has been broken near the axial plane by at least two small, nearly vertical fault surfaces. The massive Montebello sandstone rises in a great arch. Beneath its protective cover, older beds appear. The barren Marcellus black shale is recognized by its stratigraphic position and lithology where well-exposed in a quarry on the south limb. It overlies there the Selinsgrove limestone which in turn may rest directly upon the Ridgeley sandstone, since there is little evidence for believing the Esopus or Needmore to be here present, although it does occur in Perry County. Cleaves reports no Shriver here, and indeed in a small cave at the foot of the mountain, the Ridgeley sandstone is in contact with cherty Helderberg limestone. From the limestone I personally have collected *Eospirifer macropleurus.* This bit of the New Scotland formation is the oldest rock in the section.

Proceeding south from Half Falls Mountain, the Montebello sandstone is again encountered in Mahanoy Ridge. The great Perry County thrust fault separates Mahanoy Ridge from the south slope of Half Falls Mountain. It has a throw of upwards of 1000 feet, and has served to bring up the Montebello a second time in a long, narrow fault block running west far into central Perry County. Southward, the section rises steadily. Shale in the upper part of the Mahantango above the Montebello sandstone contains in its uppermost part the usual *Vitulina pustulosa* zone, making the top of the Hamilton group easily distinguishable. A magnificent Portage sequence follows.

The base of the Portage directly overlying the *Vitulina* zone of the highest Hamilton of Moscow age, is the Tully. This member is known eastward in Schuylkill and Carbon Counties, and I commented upon the Laurens in Monroe. Here, on the Juniata, for the first time is limestone as well as shale carrying not only the Tully guide fossil, *Hypothyridina venustula,* but a plentiful faunule replete in Tully elements or associations. Nearly barren, black Burket shale follows; then more or less sandy, gray to greenish shale and thin-bedded sandstones. This latter carries Naples fossils and is correlated thereby with the Harrell, but is thought by its color to represent also the "fag-end" of the Brallier. The section next exposes the Losh Run shale, truly a faunal zone rich in *Reticularia lævis.* This, I observed before, is a splendid key bed as its lithology and fauna are both distinctive, and it is widely spread through the lower valleys of the Susquehanna and Juniata. Immediately under the Losh Run shale (north in section) the beds have been folded in one of the most complex bits of flexural structures to be seen in the Devonian in Pennsylvania (Figure 89).

The succeeding Trimmers Rock sandstone needs but a passing comment. Its Ithaca fauna, that is, sandy facies Portage invertebrates, is abundant and distinctive. At its top are a few feet of rather heavy, chocolate-colored beds whose few fossils, coupled with its stratigraphic position, place it (questionably) in the Parkhead. Section 7 is approximately at the eastern limit of the Chemung. "*Spirifer*" *disjunctus* appears first in thin green shales interbedded with red beds above the supposed Parkhead, and recurs some hundreds of feet higher in the thin Kings Mill white sandstone and the brown Delville beds. From here west and northwest the Chemung fauna appears in an ever-thickening wedge driven between the Portage and Catskill. The Catskill on the lower Juniata is without important elements, barring the recurrent Chemung faunules. A remnant of the Honesdale is retained and forms a shelf or bench along the north side of Peters Mountain east of the Susquehanna River opposite Duncannon. A Triassic sill or dike cuts the Catskill north of Amity Hall, but it is thin and of no correlative value.



Photograph by George H. Ashley

Figure 89. **Highly contorted Portage sandy shales on Juniata River south of Half Falls Mountain, Perry County.**

Northern Series

Section 8, Everett.—Turning now from the eastern series to the northern, I shall commence the discussion with a section drawn east-west through Everett in east-central Bedford County. Beginning at the west side of Warrior Ridge west of Everett, the section runs east along the Raystown Branch of the Juniata River for about six miles.

Warrior Ridge is supported by the Oriskany, composed of both Ridgeley sandstone and Shriver chert. These formations are here differentiated on the dual evidence of lithology and characteristic faunal elements. The Helderberg is exposed west of the ridge. In this part of Pennsylvania the Onondaga is practically all shale with little or no limestone except locally at the top. It is the Needmore shale, cited in an earlier chapter of this bulletin. Dark when fresh, the Needmore must often be separated from the succeeding Marcellus by its fauna, of which *Anoplotheca acutiplicata* is an outstanding and abundant fossil. In south-central Pennsylvania the Marcellus is fissile, black shale, but is more fossiliferous than is usual in the east. The fauna, characteristic as a whole, must be used with circumspection here and increasingly so northward because these fossils recur in fissile, black shale among the non-fissile gray or brown shales of the lower part of the Mahantango formation. The shaly Mahantango is abundantly fossiliferous. In Bedford County it is divisible by a median sandstone into three nearly equal parts. Locally, rather definite faunal zones are observable. The absence of what might be normally construed as the equivalent of the Moscow facies was mentioned as indicative of an hiatus in these parts. Because of this condition, no *Vitulina pustulosa* zone occurs in the top beds of the Hamilton, and lithology and the appearance of the lowest Portage fauna must therefore determine the top of the group.

The Portage in the Everett section is ushered in by the Burket black shale. It lies directly upon the Hamilton with no vestage of Tully here. Harrell shale with a Naples faunule follows. The rest of the Portage, except for a little pebbly Parkhead sandstone at the top, is greenish Brallier shale with little sand. The Chemung is thick and fossiliferous. Its base is recognized, not so much by the advent of "*Spirifer*" *disjunctus,* which is exceptionally rare here, but by the abrupt invasion of quantities of "*Ambocœlia gregaria.*" This characteristic zone is wide-spread and is a recognized feature of the lowest Chemung in central Pennsylvania and south-central New York. The literature mentions certain Chemung conglomerates, particularly in Bedford, Blair and Huntingdon counties. There is no question of their presence, and they occasionally are of sufficient thickness, durability and areal extent to produce small ridges or benches. However, I have found them all so similar in lithology and faunas as to be practically indistinguishable. My own feeling is that they are probably too lenticular and of too uncertain identity to be used as trustworthy key beds.

The Catskill here began to form about middle Chemung time. Although locally undifferentiated, it is important to remark that west and northwest from here, in some sections along the Allegheny Front, one observes a cross-bedded, greenish sandstone at or near the contact between the red beds and the basal Pocono ("Berea") sandstone and conglomerate. This is thought to be a remnant of the Oswayo of north-central Pennsylvania. No evidence, lithologic or topographic, is known in south-central Pennsylvania or along the Allegheny Front which would lead me to believe that the Honesdale sandstone extends so far west.

Section 9, Eichelbergertown.—Section 8 is in east-central Bedford County. Section 9 has been drawn through Eichelbergertown, in the northeastern part of that county. It crosses the same sequence and much the same structures as does Section 8, but is shorter, owing to absence of folding in the Catskill at the eastern end. Starting in the Helderberg and Oriskany west of the village, this section runs east and stratigraphically up to the Pocono in Saxton Mountain.

Although the Eichelbergertown section is not far from that at Everett, it has several features that are different, and for this reason it is introduced for comparison. The Lower Devonian is quite like that of the Everett succession, as too are the Onondaga and Marcellus. The Mahantango shows a difference in that the middle sandstone of the southern section has split. Still no evidence for the presence of the Moscow is known. The Portage commences with a few inches of true Tully limestone. Recalling that this is absent at Everett and observing likewise that about two feet are known at Tatesville half way between Everett and Eichelbergertown, the gradual invasion of lime-depositing Tully waters may be visioned. The remainder of the section needs no additional comment save to note that the Parkhead was not found, nor have I recognized any beds of Oswayo-like lithology at the top of the Catskill.

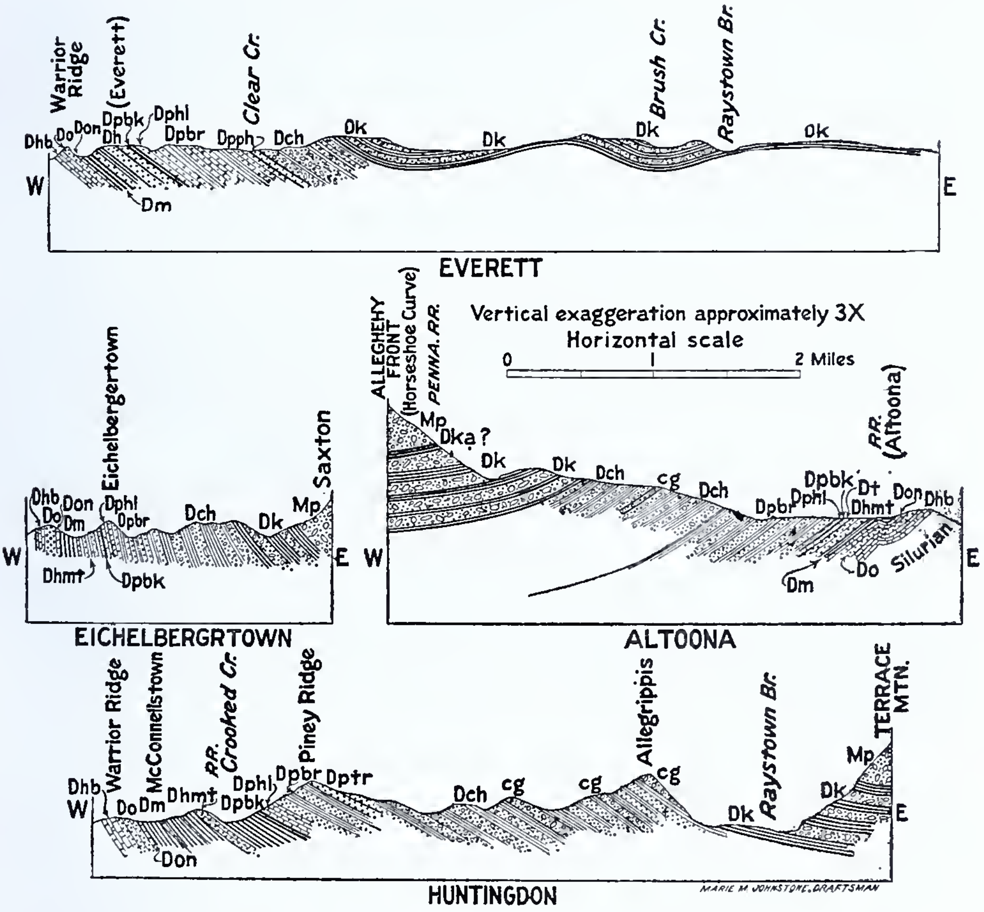


Figure 90. **Geologic cross sections, generalized, vertical scale exaggerated, at Everett, Eichelbergertown, Altoona and Huntingdon. See Figure 86 for key to localities and symbols.**

"N. B. "Dkd?" in the Altoona section stands for Oswayo.

Section 10, Altoona.—Butts (22) immortalized the Altoona section, which is essentially that found on the main line of the Pennsylvania Railroad below Gallitzin, around the famous Horseshoe Curve, and past Altoona. In this classic locality, the order is reversed stratigraphically from the Bedford County sections in that the higher beds are on the west. As one climbs the Allegheny Front, the regular stratigraphic sequence shows in ascending order.

Starting from the east end of Section 10 southeast of Altoona, near the headwaters of Beaverdam Branch, the Helderberg and Oriskany are observed. Hamilton exposures are poor, but immediately overlying the top of the group one foot of limestone reported by Butts represents the Tully. This section runs close to Burket, the type locality for the black shale of that name. A great thickness of the Brallier shale is seen along the railroad. Much of the shale is rather sandier than in some neighboring sections. No sure identification of the Parkhead has been made here, although the fauna evidently runs as far north as Huntingdon County. The Chemung is thick, and Chemung faunules recur among the lower red beds of the Catskill. The Catskill carries an Oswayo-like, cross-bedded, greenish sandstone near its top.

The rocks in the Altoona section, like most of those along the Allegheny Front, dip gently west or northwest, but no other structures of importance appear until the lower end is reached, where the beds are folded. Chemung conglomerates make small benches on the "Front" in this region.

Section 11, Huntingdon.—An east-west section in north-central Huntingdon County, immediately south of Huntingdon borough, has been prepared. It commences in Warrior Ridge at the west side of McConnelstown, and runs east to embrace the basal Pocono of Terrace Mountain.

This section is much like those at Everett, Eichelbergertown and Altoona, but differs slightly from each. The Lower Devonian, commonplace enough, is well exposed in this region. The Onondaga is still principally shale, but the Marcellus now begins to carry thin beds of limestone or rows of limestone nodules. Thin sandstones split the remaining Hamilton shale. There is no known Tully in this region. In the section drawn, the Hamilton and Burket make contact, Harrell and Brallier follow. The upper half of the Portage is assignable on both lithology and fauna to the Trimmers Rock sandstone. It will be recalled that this sandstone is absent in Bedford County, but that the Brallier at Altoona is somewhat arenaceous. Near Huntingdon, the Portage shows the incursion of sand over mud facies. The higher beds of Section 11 need no discussion, although the thick Chemung carries several conglomerates of moderate prominence, one of which supports Allegrippis Ridge.

Section 12, Pine Creek.—Sections in Clinton and Centre counties proved too incomplete for use in this chapter. Their main interest lies in an increasing development of the Tully limestone and the rare presence of a *Vitulina pustulosa* zone at the top of the Hamilton, indication that group to be here once more complete. However, when attention is shifted northeast into Lycoming County, some excellent data are obtained. Two sections (numbers 12 and 13) have therefore been prepared. Section 12 follows the valley of Pine Creek west of Jersey Shore and is nearly on the Lycoming-Clinton county line. The older beds are to the south along the north side of the Susquehanna River. The highest beds recorded are to the north in Short Mountain composed of Pocono sandstone.

Structurally, the Pine Creek section is the most complex in either the eastern or northern series. In fact, in the general region occupied by the Lower and Middle Devonian from Lock Haven to Williamsport, both folding and faulting appear considerably to have disturbed the orderly sequence. Glacial drift and outwash obscure so much that the limited hints of structures tantalize. In the Pine Creek section, however, the exposures of the structures and the stratigraphic sequence are exceptionally complete.

The southern end of this section is drawn across the western ends of two small hills supported by Helderberg limestone. These are an instance of an anomaly which recurs continually from Blair County to Columbia County. As often as not, the Helderberg may be a ridge-maker and the Oriskany completely devoid of topographic expression. Because of this equivocal situation, one must be extremely cautious in assuming correlation by topography for the lower Devonian units. In the hills referred to, the Helderberg in the northern one rises as a broken and bent anticline. The southern hill is considered to be a small fault block thrust north, the fault surface presumably lying at the northern foot of the southern hill, because a trace of Marcellus black shale was discovered in the valley between the hills. At the underpass beneath the New York Central Railroad near the northwest corner of the northern hill, the Helderberg-Oriskany contact is exposed. The Oriskany and a little Onondaga are exposed along the railroad southwest from Jersey Shore.

Exposures are poor from the northern hill to U. S. Highway 220 west from Jersey Shore, but enough was observed to advance the hypothesis that this flat stretch is underlain by folded Marcellus black shale of undetermined thickness and a little Onondaga limestone.*

Shifting north again, a splendid section runs up the east side of Pine Creek along the railroad track. The lowest beds are assigned to the Portage. Much black shale found at Jersey Shore where the upper Hamilton should be, indicates a further crumpling of the Marcellus or the displacement of much of the higher Hamilton by black shale. At the north edge of Jersey Shore, not a mile east of Pine Creek, a quarry exposes about 75 feet of Tully overlying Hamilton shale. The Burket and the Harrell occur in this area. Because the upper Hamilton, Tully, Burket and Harrell are thought to be absent on Pine Creek, a fault is introduced in Section 12.

The Portage is about one-third Brallier and two-thirds Trimmers Rock. These beds are exposed in an overturned anticline along the

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* It is of course possible that some of the black shale may belong to the Onondaga or the Mahantango, but this has not been established.

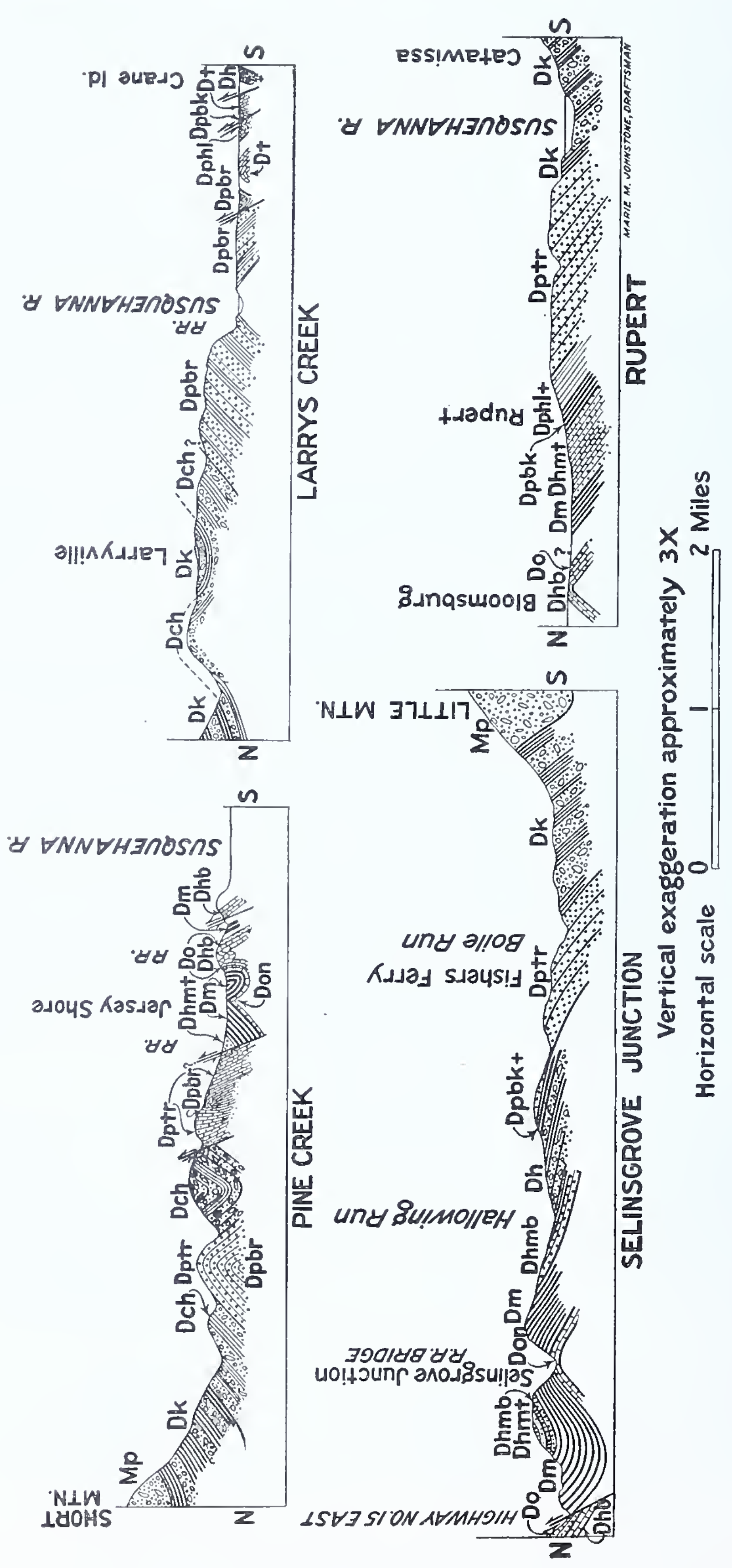


Figure 91. Geologic cross sections, generalized, vertical scale exaggerated, on Pine Creek, at Larrys Creek, at Selinsgrove Junction and at Rupert. See Figure 86 for key to localities and symbols.

railroad for about three-quarters of a mile, where they are in fault contact with the Chemung. The Chemung occupies a syncline, north of which the Portage again rises in another arch, but presently sinks once more beneath a second exposure of the Chemung. The Catskill is undifferentiated.

Section 13, Larrys Creek.—In southwestern Lycoming County, about 5½ miles east of Section 12, a section has been worked out along Larrys Creek and the Susquehanna River. Less complete than the Pine Creek section, this sequence is introduced because these sections are partly complementary. Again, structural problems complicate the interpretation.

The Lower and much of the Middle Devonian are concealed, but the Mahantango and Marcellus (or recurrent Marcellus-like shales) are poorly exposed in a few places near the Level Corner School. Their relation to higher or lower units is unknown. Along the New York Central Railroad south from Larrys Creek Station, that is, on the east bank of the Susquehanna River, two anticlines expose the Tully. This magnificent example has been fully described. Albeit there is here not less than 200 feet of the limestone, this unit was not found in the Pine Creek section. The Tully is followed successively by the Burket, Harrell, Brallier or Trimmers Rock. The last is easily found by the marked topographic change made by these resistant sandstones. The Chemung and Catskill are normal, and are exposed in some gentle folds northward near Larryville, which village occupies a shallow syncline in the Catskill red beds.

Section 14, Selinsgrove Junction. (167, 232, 265)—It is a long jump across country from southwestern Lycoming County to west-central Northumberland, but no satisfactory, complete Devonian section has been discovered in the intervening territory. At Selinsgrove Junction, however, there is a justly famous one which has been successively studied and discussed in varying completeness since the days of the First Survey. This section both geographically and geologically is intermediate between the northern and eastern series, and as such can be shown to partake of the peculiar characteristics of each. The section commences on the Pennsylvania Railroad about one mile north of the railroad bridge across the Susquehanna River to Selinsgrove. It runs south along the railroad and highway to the north flank of Little Mountain. Unfortunately, the term Little Mountain has been applied to more than one ridge in Pennsylvania. This Little Mountain must not be confused with the one in southern Perry County mentioned in section 6 of the eastern series. Structures of the Selinsgrove Junction section are quite simple. The older beds are at the north end.

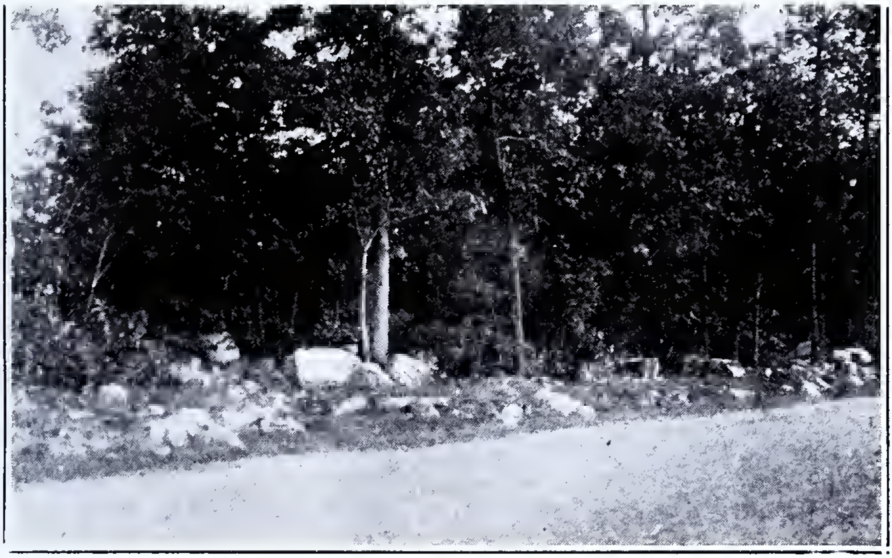
The north end of the Selinsgrove Junction section includes the south limb of a broad, low anticline that brings up the Helderberg and underlying Silurian limestones and limy shales. Along the south limb there appears to be a small thrust fault running east up a valley followed by U. S. Highway 15, for the Ridgeley is probably absent, and no Onondaga limestone or shale was found, although both are present in the area. The Marcellus is here a black shale nearly 400 feet thick. More complete exposures south of Sunbury, but beyond the northern end of Section 14 display this shale to advantage. In its lower part are large, ellipsoidal concretions. A few thin sands in its middle portion are supposed to equal the much thicker Turkey Ridge and Mexico sandstones of Juniata County. The Montebello sandstone, probably less than 40 feet thick, is present in this section. This is to be anticipated when we contrast its maximum development in Dauphin and Perry counties with its total absence in Lycoming (compare Sections 6 and 7 with Sections 12 and 13.) The *Vitulina pustulosa* zone occupies the top of the Hamilton. A mile south of the first anticline, a second arch rises opposite the railroad bridge. Though somewhat steeper, it is a lower fold than the northern anticline. Consequently, the oldest observed beds belong to the Oriskany and are exposed as ledges in the river during low water. The lower Onondaga shale has been called Esopus, but might also pass for the Needmore. This is the type region for the Selinsgrove limestone, which has recently been newly exposed in highway cuts across the southern anticline. The Selinsgrove limestone is more prominent than the limestone in the Onondaga group of the northern series, and it is better developed here than in the eastern series, though considerably thinner than its correlate, the Buttermilk Falls limestone of Monroe County.

I have observed fossiliferous Tully shale and limestone both east and southeast of the Selinsgrove Junction section, but none surely in the section itself. However, the Burket is present and also a little Harrel with Naples fossils. Both of these are actually better exposed down river along Fiddlers Run southeast from Herndon. All the remaining Portage is assigned to the Trimmers Rock sandstone, although its lower beds carry some olivaceous shale which is no doubt a remnant of the Brallier. The *Reticularia lævis* zone (Losh Run shale) is recognized in this section. In fact, the Portage as a whole is not very different from that on the Lower Juniata in Perry County, although no Parkhead occurs in Section 14.

No Chemung is present, but the Catskill red beds follow directly upon the Portage. This condition is rather striking because traces of Chemung are known in western Luzerne, eastern Perry and west-central Dauphin counties; and the group is well-represented in Lycoming County. Nothing which could be called Honesdale was discovered in the upper Catskill, nor is there any topographic evidence for supposing it present along the north slope of Little Mountain. No trace of Oswayo-like beds was recognized at the top of the Catskill. In the absence of the Honesdale the Catskill in Section 14 resembles that on the Allegheny Front; in the lack of Oswayo-like strata, it more nearly agrees with the sequences of the eastern series.

Section 15, Rupert.—A section has been drawn through Rupert from Bloomsburg south to Catawissa in southwestern Columbia County. This section, though admittedly rather inferior, is significant when contrasted with Section 14 at Selinsgrove Junction to the west, because of certain pronounced differences.

The Helderberg comes to the surface in a long anticline, the Berwick axis, at Bloomsburg. During low water in Big Fishing Creek southwest of Bloomsburg, I observed certain relations of the Helderberg to overlying strata exposed in the creek bed. There, I interpreted the sequence to include a mere trace of doubtfully identified Oriskany sandstone resting upon the Helderberg. No Onondaga was seen. It may be present, as the limestone or shale of this group occurs both east and west of here, but my prejudice is that it is absent. The black Marcellus shale is somewhat concretionary. A fine Hamilton section shows southward. No Tully was found, though it is present about eight miles west at South Danville and northward on Little Fishing Creek. There is considerable dark shale at the base of the Portage, and a sparse Naples assemblage here. A little olive-green shale assigned to the Brallier is here unexpectedly far east. The remainder of the marine Devonian is Trimmers Rock sandstone which passes up into the Catskill continental facies in this section. Once more, no Chemung was recognized, though a remnant occurs in southwestern Luzerne County ten miles to the east.



Photograph by Bradford Willard

Figure 92. **Boulders of fossiliferous Chemung (Allegrippus?) conglomerate, southern Huntingdon County.**

COLUMNAR SECTIONS

By means of fifteen transverse sections, I have discussed the Devonian sequences in as many different places in eastern and central Pennsylvania. In a general way I have drawn attention to relations among near-by or adjacent sections, but the emphasis has necessarily been upon the individual peculiarities of each particular section. I shall now try to demonstrate the Devonian correlations on a broad scale over the same region.

For this purpose the fourteen columnar sections shown in Figure 93 have been built up. Seven of these follow much the same line as was adopted for the eastern series of transverse sections; the other seven are distributed along the region represented by the transverse sections of the northern series. Therefore, these columnar series may also be spoken of as eastern and northern respectively. None of the columnar sections is necessarily to be found in any one place. Rather, they are compilations, combinations and generalizations by counties. Thus, in the eastern series, they illustrate averages in turn for Monroe, Carbon, Schuylkill, Lebanon, Dauphin, Perry and Fulton counties. Fulton County, included here, was not represented in the transverse sections of the eastern series. The northern series illustrates Bedford, Blair, Huntingdon, Clinton, Lycoming, Northumberland and Columbia counties. Here it was possible to supply data on Clinton County, whereas no satisfactory transverse section could be drawn for it. I procede to discuss correlation by groups.

Helderberg group.—Swartz has reported in Chapter II that the Helderberg group is present throughout the eastern series except in Dauphin and Lebanon counties. From Schuylkill County it thickens to the east to a probable maximum for the State in Monroe County. In the northern series, the group remains about constant in thickness, except in Bedford County, where it increases somewhat.

Oriskany group.—Cleaves in Chapter III has described this group thoroughly. In the east it consists of a single formation, the Ridgeley sandstone, which remains thin and is so shown in the Schuylkill, Carbon and Monroe county columns. Absent in Lebanon and Dauphin, the Ridgeley reappears in Perry County. The Shriver chert formation first comes in below the Ridgeley in Fulton County, and remains a constant element below the Ridgeley all along the Allegheny Front. It thins in Northumberland County and neither Ridgeley nor Shriver is surely present in Clinton County. The total Oriskany thickness varies along the northern series, with a maximum in Huntingdon County.

Onondaga group.—The Onondaga group is wide-spread, but like the Helderberg and Oriskany groups, absent from Dauphin County. It is just barely present in Lebanon, but begins to thicken in Perry County and on into Fulton County. The group is present in south-central Pennsylvania and northward. Though not identified in Clinton County, it is doubtless there but hidden and is well known east into Northumberland County, though very thin in Columbia County. The formations of Onondaga age have a very different distribution from the group as a whole. The cherty Buttermilk Falls limestone is confined to Monroe and Carbon County sections, but as it thins westward, *pari parsu,* the non-cherty Selinsgrove limestone occupies the same stratigraphic place. This latter limestone shows in all of the other eastern and northern series columns except that of Dauphin County, where it is definitely absent, and Clinton County where it probably is present but hidden. In the most southerly transverse sections it was not recorded, but does appear in these generalized pictures for the successions in Fulton and Bedford counties.

The distribution of the Esopus and Needmore shales is analogous to those of the Buttermilk Falls and Selinsgrove limestones respec-

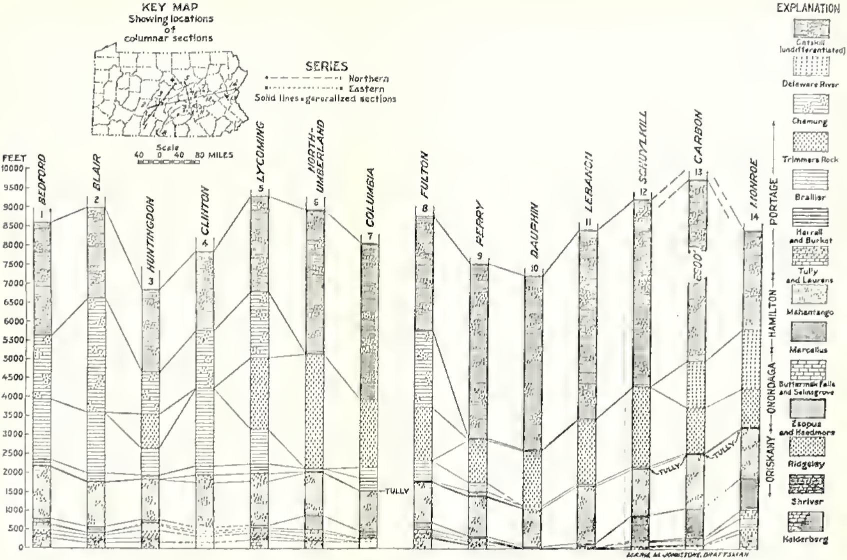


Figure 93. Correlation chart for Devonian system in Pennsylvania.

tively. The Esopus drops from a maximum in Monroe County to a somewhat thinner section in Carbon, a little less in Schuylkill, and is met no more to the west, unless a sandstone below the Selinsgrove limestone in Lebanon County be of this formation. In Carbon and parts of Monroe County, the Esopus is found to carry sandstones and cherts locally, but these are not indicated in the chart. West of Dauphin County, the Needmore shale occupies the place vacated by the Esopus. This limy, fossiliferous shale is best developed in Bedford and Fulton counties, but is encountered in most of the northern series, though concealed in Clinton County, and is probably lacking in Columbia County.

Hamilton group.—The Hamilton group is shown in the columnar sections as consisting of two formations (lesser units are omitted), the black Marcellus shale below, and the Mahantango formation above. Details are given in the chapters dealing with the Middle Devonian. The Marcellus black shale is present throughout both the eastern and northern series. Though concealed in Clinton County, it must certainly underlie this region. From a maximum in Monroe it thins to the Susquehanna and then increases to maintain a fairly uniform thickness elsewhere.

The Mahantango formation is remarkably constant in thickness. It is shown in all the columns. As it has already been thoroughly discussed, further comment would be superfluous.

Portage group.—Having commented at length on the distribution of the Tully limestone and of the Burket and Harrell shales, I need merely call attention to their thickness changes shown in the several sections of both the eastern and northern series. Of the remaining Portage, the important point to note is the facies shifts from east to west (Figure 64). Taking the Trimmers Rock sandstone as a basis, observe its lateral shift east in Carbon and Monroe counties into continental beds assignable to the lower part of the Catskill facies. In the Susquehanna Valley the sandstone dominates, but from Perry County west observe the shift from sandstone to shale as the off-lapping Trimmers Rock displaces westward the Brallier shale. In the south, this change from sandstone to shale laterally is never completed, as the Bedford County column shows only Brallier shale. The same is true in Blair and again in Clinton County, but in Huntingdon County some sandstone has crept in at the top of the column.

Chemung group.—In the sections of the northern series, the Chemung appears at the Susquehanna and spreads west in growing thicknesses. This phenomenon has been described. However, the columnar sections show how the Chemung is actually a continuation of the Trimmers Rock sandy facies of the Portage group. Thus, when the Trimmers Rock is either thin or absent, the Chemung comes in thick above the Brallier shale. Conversely, the Chemung is lacking eastward where the Portage is mostly sandstone. Not only does the Chemung represent a facies shift of the Portage sandstone upward and westward with off-lap; it also shows again the Chemung-Catskill relations over a wide area.

Catskill facies group.—The eastern and northern series of columnar sections show little if anything which has not already been described about the Catskill continental facies. Chiefly, they illustrate the lateral shift of the red beds, first in the east into the upper Portage sandstone, and then westward into the Chemung. Catskill members have been purposely omitted as their virtue has been fully extolled in Chapter VIII.

DETAILED SECTIONS

In discussing the correlation of the Devonian in Pennsylvania in this chapter, I have presented so far data intended to give a general, broad picture of the sequences encountered in different localities. Fifteen sections drawn perpendicular to the strike in as many strategic localities have been described with the help of illustrations of these cross-sections. By means of columnar sections, I have presented an exposition of the average situation by counties and explained how the lithologies change from county to county. Through these means it has been possible to point out graphically the great lithologic facies shifts across the State. The facts upon which these correlations have been founded are drawn from many detailed, "bed-by-bed" sections measured and recorded during years of field studies. Thanks to the distribution of our principal river valleys transverse to the strike of the formations, natural sections are exposed which have been enhanced by building of canals, railways and highways along the water courses. During the last score of years the extensive program of highway construction has proved a veritable mine for stratigraphic information. No longer are mountain ridges looked upon as insurmountable impediments to road-building. The modern highway engineer runs his grades over ridge after ridge, cutting deeply through unconsolidated overburden into solid rock, and exposing geologic sections which the last generation of geologists in their most sanguinary reveries never hoped to see.

It is obviously impossible to present all or even a majority of the detailed sections on file. Not only would the printing costs be prohibitive, but such a mass of data would obscure its own value. Many are repetitions of adjacent sequences and as such are essential corroboratives in preparing such a summary as the columnar sections in Figure 93. Nevertheless, it is believed advisable to publish a few, well-chosen, representative, "bed-by-bed" successions. These illustrate the type of data which form the foundation for the correlations in this bulletin, and at the same time they show the details of certain features of particular formations or groups which are not obvious in the transverse or columnar sections because of the scale to which these have been drawn.

In comparing them with the transverse or columnar sections or in checking them against the detail descriptions of formations and groups in earlier chapters, it must be repeatedly borne in mind that these sections are only a few. They have been selected because of completeness or to illustrate specific features. They are not averages; in some they can hardly be called typical because of the peculiarities for which they have been chosen. In each bed or group of beds I have noted salient features which embrace lithologic type, bedding, color, effect of weathering, texture, organic contents, degree of excellence of exposure, structural peculiarities and other unusual features and thickness. The thicknesses are measured directly, estimated, or calculated. Where a reasonable estimate could not be attained, the thickness is omitted. There are concealed intervals, and of these, where reasonably certain, a figure of probable thickness of the hidden rocks is noted down. Observations on dips, strikes, and, usually, horizontal distances are left out, nor are total thicknesses given, as they are recorded elsewhere from more comprehensive data. In two or three sections, data have been supplied from adjacent exposures to fill in concealed gaps. This is notably the case, for example, in Section O along Little Juniata Creek in Perry County where road and railroad cuts and outcrops in the stream and its banks have been used as mutually complementary. Because the sections are scattered and not necessarily in close relations to the transverse and columnar sections, they are listed alphabetically by counties. No sections are quoted for the northern tier of counties. Nearly all those recorded from there are short, broken and unsatisfactory in that everywhere, nearly, only a relatively thin portion of the strata can be measured. The published sub-surface data are far more satisfactory than surface measurements. In Chapter VIII there has already been given a fairly thorough summary of the northern tier based upon a compilation of data from many of these short sections. Chapters II and III respectively record detailed Helderberg-Keyser and Oriskany sections.

A. Bedford County, Chaneysville Section

This section deals with the upper part of the Hamilton group, showing lithologic peculiarities, faunal zones or sequences, and Middle-Upper Devonian relations where Tully and Burket are lacking. The section runs from west to east through the village of Chaneysville and is in the Clearville quadrangle.

		Feet
1.	East end of covered bridge west of Chaneysville; south of road opposite house. Oriskany sandstone, blue-white, coarse. Exposed.	4
2.	Onondaga (Needmore) shale with 1-in. limestone lenses, dark gray to black, weathers to olive-gray chips, fissile; fossils rare; exposure poor.	?
3.	Concealed interval including Marcellus and lower part of Mahantango formations.	850
4.	West apex of road triangle at Chaneysville school. Mahantango lower shale (Gander Run member) with stray sandstones, olive-gray, weathering to chunks and splinters; *Tropidoleptus carinatus* abundant in lower third, *Chonetes* at base as exposed.	30
5.	Mahantango formation (Chaneysville sandstone member, type locality), olive-gray, brown weathering, medium texture; "*Spirifer*" *mucronatus* common.	182
6.	Continuing through Chaneysville. Mahantango formation (Frame shale member), sandy with platy sandstones, light olive-gray, buff-weathering, yield chips; very fossiliferous; exposures poor.	343

		Feet
7.	Road north of Chaneysville, north of first bridge, local faulting. Top of Mahantango shale overlain by Harrell shale, gray; Naples fauna. No Burket nor Tully present. Thickness of Harrell.	38
8.	Continuing east of Chaneysville along road; cuts. Brallier shale, in contact with top of Harrell gray shale; olive, smooth bedding-surfaces, barren.	

B. Bedford County, Everett-Juniata River Section

This section is a presentation of the Upper Devonian sequence in south-central Pennsylvania, primarily to illustrate the Catskill continental facies of that part of the State. The section starts east of Breezewood and more or less follows the Raystown Branch of the Juniata River along Highway 30 (Lincoln Highway) west to Everett. It lies in the Needmore, Clearville and Everett quadrangles.

1.	On U. S. Highway 30, 100 yards east of Mt. Zion Church (Needmore quadrangle), cut. Catskill red beds. This is the first showing of the Catskill below the Pocono of Rays Hill to the east. Exposed.	17
2.	.3 miles west of 1. Scattered, broken down showings of Catskill red beds. Probably small anticline here, but exposures too poor to determine attitude or thickness.	?
3.	.6 miles west of 1, cut. Catskill red beds with thin, greenish-gray, beaded sandstone partings at intervals.	60-75
4.	.7 miles west of 1, first small rise west of road south from Breezewood. Catskill red beds. At base of exposure 15 feet of olive-drab shale. Among the red beds is a little, interbedded, whitish sandstone which weathers to rusty plates.	55
5.	Clearville quadrangle. 1.15 miles west of 1, down grade west of Breezewood. Numerous cuts in Catskill red beds with some olive-drab shales and a little mud-chip glomerate interbedded 40 feet below top. These beds probably equal to 4. Exposure partial. Near base and again 270 feet above base are green to whitish sandstone partings of beaded type. Exposed.	285
6.	Concealed.	30
7.	Continuous cut down grade to brook and thence west to curve at "A." Catskill red beds.	15
8.	Curve at "A" of "HIGHWAY." Axis of faulted and crumpled fold, sheared perpendicularly with quartz stringers in Catskill.	?
9.	Continuing down grade toward west. Catskill, partly equal to 7 and lower part of 6. "Worm eaten" beds and fish fragments near middle. The "worn eaten" beds appear to be result of out-weathering of shale pellets, not calcium carbonate. At base a 24-foot green sandstone, massive to platy, weathering brown.	99
10.	Concealed, probably all red beds.	75
11.	Cuts at and opposite road south between first "A" and "T" of "JUNIATA." Catskill red beds, slightly folded, exposed also in abandoned quarry on hillside above road to north; fish fragments 30 feet above base, above which is 20 feet of greenish, laminated sandstone.	75
12.	Partly hidden, much heavy red sandstone.	130
13.	Concealed.	30
14.	Across creek south of road, high cut cliff. Catskill, mostly sandstone, heavy, cross-bedded, attitude dubious; some greenish sandstones and plant fragments.	64

		Feet
15.	Concealed.	45
16.	Road relocated at new bridge across river. Catskill less massive than above (at 14), to shaly; partly hidden.	85
17.	At "J" of "JUNIATA." Catskill red beds, mostly massive sandstone, exposed along old road to covered bridge. (N. B. This bridge "went out" in the 1936 flood.)	175
18.	Concealed crossing river.	?
19.	West end of new bridge. Catskill, heavy red sandstone with a green lens 22 feet wide and 2 feet thick which may be channel or swamp deposit. These beds probably equal 17 and 18 east across river.	
20.	Continuing upward from approximately the top of 16 west of highway at "LINCOLN." Catskill red beds.	280
21.	Syncline at "L" of "LINCOLN."	
22.	Repetition of 20 downward.	
23.	Anticline; a 10-foot, heavy, sandstone marks arch.	
24.	Partly hidden.	100
25.	Continuing down. Large, abandoned quarry with small monoclinal fold in east end. Catskill red beds, heavy.	95
26.	Continuing west, cuts plentiful.	110
27.	Syncline at first gully east of road.	
28.	West of syncline, continuing in Catskill	150
29.	Continuing in Catskill red beds. May be some repetition here.	270
30.	Same beds as 29 repeat in fold.	
31.	Axis of syncline.	
32.	Beds exposed in high cliffs east of highway at end of curve at juncture of river and Brush Creek. Much massive sandstone, gray to greenish, cross-bedded with sweeping laminae suggesting eolian deposits, cross-bedding planed squarely off at top with short foreset beds. These break out into plates.	300
33.	Concealed.	?
34.	At sharp turn at "V" of "RIVER" (Everett quadrangle). Cuts and small glen show massive, green sandstone probably equal to 32 repeating through folding in concealed interval at 33. The beds sometimes are "worm-eaten," carry fish fragments and are ripple marked and bear mud-chip glomerates and plant fragments. Folding continues west.	430
35.	Mostly concealed, probably all Catskill and gently folded.	?
36.	First road north, west of "RIVER." Small showing of Catskill in cut.	
37.	At curve and juncture with secondary road south, cuts. Shale, brown or gray-brown, rusty to buff-weathering. Occasional thin, brown sandstones also present and some heavy beds of more or less whitish sandstone up to 4 or 5 feet thick. 60 feet above base is a 5-foot gray to pale olive-gray, coarse sandstone which may equal some of the conglomerates described by earlier workers, perhaps the Saxton. The lithology here suggests Chemung, but beds appear to be barren. ..	325
38.	Concealed along highway for about one mile.	?
39.	Cuts. Brallier shale, greenish, sandy, locally folded. Evidently the Chemung is in the concealed interval at 38. Brallier shows westward in occasional exposures to Everett.	

C. Blair County, Newry Section

The section here drawn up illustrates the lithologic and attendant faunal changes from the Hamilton group upward through the Catskill continental facies. It is particularly good in showing the displacement of the marine Chemung by the red beds. It brings in also a glimpse of the facies shift between Portage sandstone and shale. This section runs along the tracks of the Pennsylvania Railroad from a point west of Newry to the Allegheny Front. It is included on the Hollidaysburg and Ebensburg quadrangles.

		Feet
1.	East of underpass, large cuts begin at right-angle curve near Newry. Section ascends westward.	
	Marcellus shale, dark-gray, fissile, barren. Exposed.	34
	Mahantango lower shale, interbedded, gray, fissile shale and thin, more or less lenticular, gray, brown-weathering sandstones some of which appear limy.	14
	Mahantango sandstone, gray, brown-weathering with gray shale interbeds, barren.	143
2.	Concealed west across valley with road.	100
3.	Traces of dark shale in fields south of R. R.	95
4.	At mile post 36, cuts. Mahantango shale, stray sandstones, gray; fossiliferous; top concealed.	128
5.	Concealed.	380
6.	Slight curve south. Mahantango sandy shale partly hidden.	150
7.	Concealed around curve.	35
8.	Beginning of large, right-angle turn, cut. Probably Brallier, but sandy, flaggy to shaly, gray. Top hidden.	114
9.	Burket black shale below Brallier in field south of R. R. Little in place. Black, chippy, small, calcareous concretions. Passes upward into gray shale (Harrell?). All much weathered. The lower, black shale rests upon upper Hamilton sandy shale which weathers to light gray chips. No Tully seen.	?
10.	Concealed on R. R. in part and follows near-strike section in Brallier shale for about 1 mile to summit of spur.	
11.	First curve (right angle) beyond 10. Cut. Brallier, sandy shale and some flaggy sandstones, grayish; a few Ithaca fossils in fairly coarse, heavy-bedded sandstones 104 feet above base. These probably are an incursion of the sandy (Trimmers Rock) facies from the east.	194
12.	Concealed across small valley.	235
13.	At second "R" of "PA. R. R.," cut. Brallier shale, growing gnarly and sandier, carries an Ithaca fauna 80 feet above base.	220
14.	Continuous with 13. Platy to shaly sandstone; 30 feet above base "*Spirifer*" *disjunctus* appears, placing this in Chemung; top hidden.	70
15.	Chemung sandstone and shale, dominantly gray, brown- or buff-weathering, partly hidden. Fossils 70 feet above top of 14. *Ambocoelia gregaria* common as in lowest Chemung. Another faunule at 170 feet above 14. Mile post 38 near base.	220
16.	Concealed.	445
17.	Chemung sandstone in small cut; flaggy, olive-brown shale interbeds; fossils in upper part.	90
18.	Concealed.	130

		Feet
19.	Beginning at east end of curve opposite "p" of "Gap." Chemung flags, platy, sandy shale with a few heavier beds. Gray to olive-gray; fish fragment 48 feet above 18. Abundant faunule 50 to 60 feet above 18. Ripple-marked surfaces and occasional pebble beds present.	94
20.	Similar to 19. Lowest dull red shale observed, but marine fossils present at 30 and 50 feet above base.	108
21.	Concealed at curve.	205
22.	Similar to 20 but with interbedded red strata. Abundant Chemung faunules at 30, 50, 110 and 212 feet above base. This carries section to underpass at "Gap."	235
23.	Concealed, valley at underpass.	290
24.	Curve left, opposite "Gap," cuts. Chemung gray or olive-gray to brown shale and sandstone, brown-weathering; no red beds here; plant stems and ripple marks. At 40 feet above base, marine fossils.	117
25.	Concealed on curve.	?
26.	Catskill red beds. Partly hidden. Ripple marks, mud chips, mud cracks and rain prints (?). A few thin stringers of green shale.	140
27.	Similar to 26, partly hidden.	50
28.	Concealed in valley opposite "Blair."	950
29.	Curve at nose of ridge, cuts. Catskill similar to 26. Carries section to secondary road.	81
30.	Concealed.	184
31.	At sidings. Intermittent showings of Catskill red beds in cuts; interbeds of cross-bedded green sandstone of Oswayo type.	?
32.	Concealed, to west side of switch tower at yards southwest of "Run," Ebensburg quadrangle.	?
33.	West of switch tower, cuts. Catskill red beds with occasional interbeds of rather heavy, gray or olive-gray sandstone and shale which tend to weather yellow-brown; barren.	50
34.	At curve south of bridge over brook at Muleshoe curve. Pocono sandstone, massive, gray, medium-coarse, somewhat cross-bedded.	

D. Clinton County, Lockport Section

This is a short section introduced to exemplify the Tully, Burket, Harrell and Brallier relations at a point where these units are particularly well-developed. Section D starts at Lockport on the north bank of the Susquehanna River opposite Lock Haven, and runs northwestward a short distance. It is included on the Lock Haven quadrangle.

1.	At east end of section opposite West Branch bridgehead to Lock Haven. Tully limestone, light gray, weathering lighter, evenly bedded in strata that averages about 2 inches thick with thin, black shale partings. Lowest 30 feet tends to be shalier, base hidden. Topmost 10 to 15 feet grows shaly and is fossiliferous.	185
2.	Burket black shale; barren.	61
3.	Harrell shale, sandstone interbeds, dark gray, some rather olivaceous; sparse Naples fauna.	80
4.	Harrell shale, some beds finely arenaceous, dark gray to black.	75

		Feet
5.	Harrell shale, but carries olivaceous beds and evidently passing upward into the Brallier; nearly barren.	125
6.	South side of brook at secondary road. Sandstone, gray, platy. Carries sparse Naples faunule. Probably Harrell or basal Brallier.	9
7.	Concealed in brook valley at Lockport.	
8.	Brallier olive shale with interbedded gray sandstones; barren.	85

N. B. Portage and then Chemung beds continue up the river on both sides and pass over eventually into the Catskill.

E. Columbia County, Catawissa Section

This sequence on the North Branch of the Susquehanna River is introduced to portray the Portage-Catskill relations in the absence of the Chemung. Williams and Kindle (265) described a similar section to this along the east bank. This one starts at the Reading Railroad bridge and continues south along the west bank. Its lowest beds are concealed, but may be supplemented near Bloomsburg. The section is included in the Catawissa quadrangle.

1.	Mahantango sandstone, flaggy to submassive and massive, some shaly bands, gray, brown-weathering; fossils abundant in bands and have calcareous shells preserved in many examples, others occur in soft, limonitic layers.	160
2.	Concealed save for small showings similar to 1.	635
3.	Mahantango sandstone, gray, shaly.	7
4.	Concealed.	24
5.	Similar to 3.	9
6.	Concealed.	28
7.	Similar to 3, but greenish; crinoid "joints."	16
8.	Concealed.	21
9.	Mahantango formation sandstone, rather shaly, gray-green, weathering gray; fragmentary fossils.	25
10.	Sandstone similar to 10 but very massive.	7
11.	Sandstone, massive to submassive. Fragmentary fossils. Upper part concealed at small gully. This probably includes the Burket and perhaps some Tully	50
12.	Sandstone, gray, shaly, partly hidden. Presumably this is basal Trimmers Rock sandstone.	65
13.	Concealed.	21
14.	Shale, gray, sandy with some submassive sandstones, partly concealed.	20
15.	Trimmers Rock sandstone, flaggy, gray, very hard; carries Ithaca faunule.	35
16.	Similar to 15, partly hidden, fossils at base, grows shalier toward top. These beds form ridges and cliffs up hillside.	?
17.	Concealed.	210
18.	Trimmers Rock sandstone, flaggy, gray, weathers gray to brown, cross-bedded. Some shaly beds.	17
19.	Concealed.	36
20.	Similar to 18.	12
21.	Concealed.	8
22.	Shale, gray, rather arenaceous.	23
23.	Sandstone, shaly, gray, weathers brown to white; grades down into 22. Partly concealed.	75

		Feet
24.	Concealed.	15
25.	Sandstone, massive, flaggier upward, gray. This at "m" of "Bloomsburg."	140
26.	Sandstone, flaggy, gray.	40
27.	Concealed.	20
28.	Shale, gray, sandy.	30
29.	Similar to 28, partly hidden.	119
30.	Sandstone, massive to flaggy, gray, partly hidden.	?
31.	Concealed to culvert "1/63"	20
32.	Sandstone, flaggy to platy, gray to brown, weathering to slightly reddish tint, some greenish interbeds, fragmentary fossils.	175
33.	Sandstone, massive, gray, brown-weathering.	12
34.	Sandstone, rather massive to flaggy, chocolate-brown. Beds 32-33-34 mark lowest indication of Catskill facies.	10
35.	Shale, brown, sandy.	12
36.	Sandstone, massive, brown.	6
37.	Sandstone, chocolate-red.	4
38.	Sandstone, flaggy to submassive, brown.	42
39.	Shale, dark red.	3
40.	Sandstone, massive, brown.	8
41.	Shale, chocolate.	5
42.	Sandstone, massive to shaly, brown, partly hidden.	85
43.	Sandstone, very massive, brown.	6
44.	Shale, sandy to platy sandstone, brown.	28
45.	Sandstone, massive to flaggy or platy, brown with some greenish to gray beds.	75
46.	Sandstone, platy to submassive, gray-brown.	15
47.	Sandstone, platy, chocolate-red.	20
48.	Sandstone, flaggy, chocolate-red, gray at base.	25
49.	Sandstone, very massive, gray, brown-weathering.	25
50.	Sandstone, flaggy to massive, chocolate-red to brown.	25
51.	Sandstone, mostly massive but some flaggy beds, brown.	35
52.	Sandstone, flaggy to shaly, brown, partly hidden. Grows shalier upward; poorly preserved brachiopods.	95
53.	Concealed, probably brown shale.	15
54.	Sandstone, massive, brown, weathers light-gray.	30
55.	Shale, fissile to sandy, growing platy upward, gray.	48
56.	Shale, flaggy dark to bright red, exposed in gully.	30
57.	Concealed.	15
58.	Shale and sandstone, chocolate-red to dark red.	28
59.	Sandstone, massive, brown.	3
60.	Similar to 58.	15
61.	Sandstone, flaggy, dark gray or greenish-gray to brown.	45
62.	Sandstone, flaggy to massive, chocolate-red with green bands.	60
63.	Sandstone, submassive to flaggy, gray.	4
64.	Sandstone and shale interbedded, dark red, occasional brown sandstone bands, partly hidden at culvert "1/84"	425
65.	Sandstone and shale, massive to platy, greenish-gray. This is at end of concrete highway at curve west. Partly concealed.	65-70

		Feet
66.	Sandstone, flaggy, dark red.	84
67.	Partly concealed. A little dark red sandstone shows. This carries section to Delaware, Lackawanna and Western depot at Catawissa.	

F. Dauphin County, Rockville Section

A unique feature of the Hamilton group of central Pennsylvania is the appearance of heavy, thick, but local sandstones. This section in the quarries across the end of Little Mountain, is used as an illustration of the most prominent of these sandstones, the Montebello, which occupies most of the Mahantango formation here. This sequence commences at the north end and terminates in the small valley north of the Pennsylvania Railroad bridge, and traverses the end of Little Mountain. It is found on the Harrisburg quadrangle.

1.	Sandstone, flaggy to submassive with scattered pebbles of white quartz; large "*Spirifer*" *granulosus* in coarser beds.	110
2.	Sandstone, heavy, and white quartz-pebble conglomerate; large "*Spirifer*" *granulosus*, etc. Corals, may equal Centerfield.	19
3.	Sandstone, somewhat shaly, dark, occasional plant fragments. *Taonurus* in shalier beds, brachiopods common.	15
4.	Shale, dark gray, and sandy shale, vast numbers of communited plant fragments.	18
5.	Sandstone, flaggy to massive, gray, coarse; occasional brachiopods and plant stems.	42
6.	Sandstone, heavy, hard, gray, dense. Fucoids more or less carbonized at north side of small tunnel in quarry wall.	62
7.	South end of quarry. Sandstone, dark, shaly, full of plant fragments.	6-7
8.	South wall of quarry. Sandstone, abundant brachiopods.	1
9.	Interval between northernmost and middle quarry. Sandstone, partly concealed.	180
10.	Middle quarry. Shale, partly hidden.	?
11.	Sandstone.	120
12.	Southeast corner of middle quarry. Sandstone, heavy, with scattered quartz pebbles; "*Spirifer*" *granulosus* plentiful	80
13.	Interval between middle and southernmost quarry. Shale, sandy, dark; partly hidden.	150
14.	Southernmost quarry. Shale, dark and sandy and dark shale, with massive, 4-foot lower sandstone (Fort Hunter member, type locality). *Taonurus* in associated shale. Base in Marcellus black shale.	75

G. Fulton County, Needmore Section

Measured in southern Fulton County, this succession is one of the most complete of the Devonian in southcentral Pennsylvania. It is particularly interesting in its exposition of the Hamilton lithology and faunal sequences and may be profitably compared with sections A and F. The section commences in an up-faulted Devonian exposure in cuts on Highway 522 opposite Lowery Knob at the north end of Dickeys Mountain and runs southwestward along the highway. The Needmore quadrangle includes this region.

		Feet
1.	West edge of Webster Mills. Helderberg limestone partly exposed north side of road.	45
2.	Concealed at stone wall. Oriskany float.	50
3.	West end of wall. Marcellus (?) shale, black, graphitic, irregular fracture and appears severely crushed. Partly hidden.	15
4.	Concealed in small valley northward.	125
5.	Cut bank. Shale, thin-bedded, olive-green, some dark Marcellus-type of beds, some laminated; a few fairly arenaceous. Only fossils seen were crinoid "joints."	24
6.	Marcellus black shale, some beds weathering to nearly white Chips, a characteristic of the formation in these parts. Contact with 5 appears sharp. (5 may be black shale of Onondaga).	145
7.	Mahantango formation sandstone, thin-bedded to platy, olive-green, brown-weathering or buff, fine-grained. Grades down into 6. Partly hidden. Fossiliferous 60 feet above base. Faunule reminiscent of Fort Hunter member of Susquehanna Valley.	155
8.	Concealed.	65
9.	Sandstone, like 7 but platier and somewhat coarser, partly concealed, weathers to dark, irregular pieces; barren.	95
10.	Concealed.	55
11.	Sandstone, platy to flaggy, gray, gnarly, some beds somewhat fissile and shaly, medium-grained, brownish-weathering. Highly fossiliferous in zones: collected at intervals: 1st zone, 40′ below top, small *Tropidoleptus carinatus* 2nd " 180′ " " , large *T. carinatus* 3rd " 215′ " " , large "*Spirifer*" *mucronatus* 4th " 240′ " " , pelecypods 5th " 325′ " " , large "*Spirifer*" *mucronatus* and *T. carinatus*. Total	335
12.	Sandstone, flaggy to submassive, hard, medium gray, brown- or gray-weathering, medium texture; barren save for fucoids and *Taonurus*.	45
13.	Similar to 12, in fact 11, 12 and 13 really all one unit.	38
14.	Sandstone, heavy bedded to massive or flaggy, blue to olive-gray, brown-weathering. Much like underlying units, but somewhat heavier and very hard. Fossiliferous. "*Spirifer*" *audaculus*, etc. present, also fucoids and *Taonurus*.	40
15.	Sandstone, platy, olive-gray or olive, brown-weathering. Chippy to fine shale beds present suggesting Burket, but has *Elytha fimbriata*.	45
16.	Concealed.	140
17.	Brallier (and Harrell?) shale, best seen on old road grade at side of road north. Characteristic greenish shale and some thin sandstones. About 10 feet from top is red-brown shale. Naples fossils near top. Partly hidden. Thickness about	240
18.	Concealed interval follows about which nothing could be ascertained, across valley of Big Cove Creek. Estimated thickness	930
19.	Cut banks immediately north of junction of Highways 522 and 928. Shale, platy, olive to dark brown, weathering light brown and chippy. Some finely arenaceous beds. Partly concealed, but appears to contain some red-brown shale intervals and also a little Brallier type of shale. All nearly barren.	34
20.	Trimmers Rock sandstone, platy, olive-brown, rusty-weathering, medium texture, mostly hidden, Ithaca faunule in tiny gully north side of road.	75

		Feet
21.	Mostly concealed up-grade along new highway southwestward. "*Spirifer*" *disjunctus* collected in small, ferruginous lens 4 inches thick in gutter and a second marine faunule 640 feet above base. It seems probable that there is some faulting in this section.	875
22.	Small cuts. Catskill red beds with a little non-red, also small showings of gray flags in highest 20 feet. Partly hidden.	440

H. Huntingdon County, Entriken Section

This section shows something of the Catskill sequence in a region where that facies contains relatively prominent conglomeratic bands. The section begins at a cross-roads in Little Valley on Tatman Run, and continues northwest. It is on the Huntingdon quadrangle.

1.	At cross-roads, B. M. 1004. Mauch Chunk-Pocono contact here appears to be non-transitional.	
2.	Pocono sandstone. Thickness not determined. Continuing down grade.	
3.	At secondary road along west face of Terrace Mountain. Highest observed Catskill red beds, detected by soil color.	
4.	Catskill red beds, 5/8 miles west of 3; attitude uncertain.	
5.	Concealed across Juniata River, Raystown Branch.	
6.	Side road west, end of Entriken Bridge, road relocated to northwest. Catskill red shale in small, abandoned quarry.	
7.	Relocated road. Catskill red shale and a little gray, sandy shale show intermittently westward.	220
8.	Continuous with 6 downward. Sandstone, gnarly, and shale, olive-green to olive-gray, brown-weathering.	25
9.	Conglomerate, gray, hard, sandstone matrix, heavy bedded, pebbles fairly well sorted, average diameter ¼ inch, but occasionally up to 1 or 1.5 inches. Mostly white quartz and a few, small, dark ones of softer, undetermined material. One red jasper pebble ¼ inch diameter found. Rounding good in majority of pebbles which are mostly oriented with short axis perpendicular to bedding; *not* a flat-pebble conglomerate*.	4′-9″
10.	Continuing along road, lithology identical with 8. A few pebble lenses at intervals.	5′-6″
11.	Shale, olive-green to olive-brown, brown-weathering, weak; some brown or gray sandstones, platy to submassive, also present. A little dull red-brown shale here. Pebble lenses in lower part.	42
12.	Catskill red sandstone and shale with occasional brown or greenish beds.	57
13.	Concealed.	25
14.	Similar to 12.	22
15.	Concealed.	37
16.	Similar to 12.	63
17.	Shale and sandstone, olive-gray or brown, brown-weathering, some red interbeds.	24
18.	Concealed.	95
19.	Sandstone, flaggy, gray.	7

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* N. B. 9 is doubtless I. C. White's Allegrippus conglomerate which he called the lower conglomerate 1000 feet below his Lackawaxen. It lies in valley of Raystown Branch and makes no ridge here. White (230) reported "no red beds" beneath the Allegrippus, but here are plenty. He called enclosing red beds Catskill-Chemung, but I have found no fossils in this section thus far, though Chemung occurs in this county.

		Feet
20.	Shale, brown, weathering to brown or rusty chips; thin sandstone lenses. Base hidden.	50
21.	Concealed along road for 0.3 miles. Chemung?	
22.	¾ mile from bridge, cuts. Trimmers Rock sandstone, platy to flaggy, gray, brown or greenish, weathering rusty or reddish; fucoids and crinoid "joints."	35
23.	Concealed.	97
24.	Cuts continue west. Sandstones and some shale, inter-bedded gray and brown. Sandstone flaggy to submassive to near-conglomerate coarseness, as a 1-foot bed 3 feet above base.	84
25.	Concealed along road for 0.4 mile.	?
26.	At road fork and gap in Piney Ridge, cut. Brallier (?) shale, rather sandy, olive-gray, weathering rusty, some fairly heavy sandstones, but shale clayey.	143
27.	Brallier shale, olive-gray with a few thin sandstones.	22
28.	Concealed southwestward along road.	?
29.	Near school, south-southwest of B. M. 823, cuts. Brallier shale, a few sandstone lenses, greenish, brown-weathering; barren.	35
30.	Concealed at school.	85
31.	Opposite school, cut. Same lithology as 29.	84
32.	Concealed around curve in road, probably 29 repeated.	
33.	At secondary road intersection ¼ mile east of Entriken. Harrell shale, rather fissile, dark gray, weathers light-brown; Naples fauna. Top in sharp contact with olive-green Brallier.	60
34.	Concealed. Approximate thickness	50
35.	Mahantango formation, shale, some small nodules, olive-gray, sandy, brown-weathering, chunky. Fossiliferous.	47
36.	Mahantango formation. Sandstone, hard, flaggy, gray. *Taonurus*. Base hidden.	6
37.	Concealed.	195
38.	East side of railroad. Mahantango sandstone, hard, submassive, gray to olive-gray, some platy beds and nearly fissile. Forms small ridge.	23
39.	Concealed to R. R.	
40.	Cut bank and abandoned quarry facing R. R. north of underpass and east of track. Mahantango interbedded flags and shale, dark gray; faunule suggests Marcellus recurrent.	25
41.	Concealed through Entriken.	
42.	At B. M. 947, Helderberg limestone in small knoll or ridge at old kiln and small, abandoned quarry.	

I. Huntingdon County, Shade Valley

Section I is drawn in a region near the border line of the eastward extension of the Chemung sea. Absent here, marine Chemung occurs in northcentral Huntingdon County and in Perry County. In this section the Portage passes upward into red beds. The facies shift of the Portage sandstones and shales is illustrated. This section includes the striated surface from which it has been deduced that there was ice in the Portage sea. This section follows Highway 829 across a syncline between Shade Valley and Blairs Mills. From Blairs Mills to the synclinal axis, exposures are few and poor and fail to supply consecutive data. The section actually starts, therefore, at the axis about 1.25 miles east of Shade Valley cross roads (Richdale of Second Survey) and continues east to Shade Valley. This sequence is plotted from the County Road Map; no topographic map.

		Feet
1.	At axis of syncline, 1.25 miles east of Shade Valley. Catskill sandstone, brown to olive-brown, brown-weathering, some red-brown interbeds, medium coarse. Soil here more or less reddish and dull red and brown float rock.	5
2.	Trimmers Rock sandstone, shaly to platy, olive-gray, brown-weathering and buff; some shale of same tints. Partly hidden. Small dry gully north of road paved with red-brown or gray sandstone float, some of it fossiliferous. No "*Spirifer*" *disjunctus* found. Red beds apparently come in about 100 feet above these fossiliferous strata. Estimate thickness	115
3.	Concealed for .15 miles, valley north at Sawmill Road.	
4.	Trimmers Rock sandstone, small exposures north of road, platy to shaly, gray, brown-weathering, probably continuous with 2.	17
5.	Concealed for 320 feet save for occasional small showings like 4.	
6.	Intermittent showings of platy to flaggy sandstone, gray, brown-weathering.	45
7.	Concealed.	30
8.	Similar to 6, partly hidden. A little red-brown sandstone present in float.	35-40
9.	Concealed.	30
10.	Trimmers Rock sandstone, platy, hard, gray, brown- to red-brown-weathering, medium texture. Partly hidden; crinoid "joints."	85
11.	Concealed.	18
12.	Sandstone like 10 but platier.	13
13.	Brallier-like shale, sandy, platy, olive-gray, brown-weathering.	14
14.	Concealed.	40
15.	Trimmers Rock sandstone, flaggy to platy like 12 and 13, gray to olive-gray at base; middle part carries 20 to 30 feet of rather massive beds; plant stems, large and carbonized, mud chip bands, mud cracks, "worm" trails, *Fucoides graphica*. Carries section to side road.	195
16.	Concealed, valley with road north.	20
17.	Sandstone, platy like 15. Exposed bedding surface about 30 by 30 feet, striated and gouged in direction N. 73° W. These mark closely similar to glacial striae and would be so-called in glaciated region. Surface clearly exposed by stripping during road construction, but marks not those of pick or power shovel. Direction of movement seems to have been northwest, per evidence of scratches which broaden in that direction. Widest about 1.25 inches and about ½ inch deep, but most are ½ by ⅛ inches and all parallel. Rock attitude: strike N.37°E; dip 26°S.	98
18.	Concealed.	125
19.	Harrell shale, sandy, chippy dark gray; *Aulopora*.	10
20.	Shale similar to 19, but lighter and sandier with *Vitulina* and other Hamilton fossils. Partly hidden.	20-25
21.	Shale, sandy, clayey, platy, light to olive-gray or buff, weathering to red chips. Approximately	10
22.	Sandstone, flaggy to shaly, olive-gray, brown-weathering, medium coarse, Hamilton faunule.	8
23.	Shale, clayey, sandy, platy, olive-gray, brown-weathering; yields irregular chunks.	?

		Feet
24.	Sandstone, submassive, olive-gray, light brown-weathering, fine texture, fossiliferous, *Taonurus.*	7
25.	Sandstone, clayey, shaly, much like 24. *Tropidoleptus carinatus* abundant near base, suggesting Deep Run shale.	30
26.	Sandstone, flaggy, olive-gray, brown-weathering, fine texture, much like 24; fossiliferous.	14
27.	Sandstone, massive, gray, brown-weathering, medium texture.	5
28.	Sandstone, flaggy to submassive, olive-gray, brown-weathering, medium texture, breaks up to very irregular chunks. This opposite road south. Base hidden	37
29.	Partly hidden. Sandstone, platy, olive-gray, fine-grained. weathers to tiny parallopipedons; fossiliferous	60-75
30.	Sandstone, flaggy to submassive, olive-gray, brown-weathering, medium texture; fossiliferous, large *Tropidoleptus*	9
31.	Sandstone, very massive, like 27	10
32.	Sandstone and shale interbedded, olive-gray to dark gray- or brown-weathering, partly concealed. Beds at 30, 31, 32 appear to support small ridge here. This is characteristic of certain sandstones in the Hamilton in this general region of central Pennsylvania	195
33.	Sandstone, massive, some platy interbeds, dark-gray, brown-weathering, medium texture	25
34.	Sandstone, like 32, but flaggy; partly hidden	35
35.	Sandstone, like 33	28
36.	Sandstone, like 32, partly hidden, base concealed, some gnarly beds; coquinte with large *Tropidoleputus*, *Tentaculites*, gastropods, etc. This carries section to school in main valley road to Shade Valley	60
37.	Turning north along Trough Spring Creek: Quarry at road side ½ mile north of school along near strike section therefrom. Shale, dark gray, red-brown-weathering, some pencil fracture beds; some beds finely arenaceous. This approximately underlies 36.	

J. Juniata County, Delaware Creek

Section F in Dauphin County illustrates the character of the Montebello sandstone which takes up most of the Mahantango formation there. This sequence shows the character of the analogous Turkey Ridge and Mexico sandstones which locally occupy much of the Marcellus. The Marcellus-Onondaga relations also are exemplified. This succession has been drawn from Thompsontown northward along Delaware Creek and Highway 135 and is included on the Millerstown quadrangle.

1.	First ridge north of Thompsontown borough line. Small showing of sandstone, massive to flaggy, olive-gray, medium-grained, barren. This is ridge-forming, Turkey Ridge sandstone	35
2.	Concealed; road crosses valley of Delaware Creek	385
3.	Road cuts an abandoned quarry at point where curve has been eliminated. Sandstone, massive, olive-gray, brown-weathering, medium coarse. May be continuous with 1, but higher.	35
4.	Concealed; probably same as 3	22
5.	Sandstone, flaggy to platy, olive-gray, brown-weathering, medium grained; partly hidden, local crumplings and distortion	50

		Feet
6.	Concealed	70
7.	Abandoned quarry. Sandstone, platy to shaly, gray, brown-weathering, upper beds weather brown on bedding surfaces, locally distorted. Mexico sandstone	100
8.	Road cuts continuous with abandoned quarry at 7. Sandstone, massive to flaggy, very hard, gray, dark-brown-weathering, medium to coarse texture. Some beds verge upon fine conglomerate with occasional white quartz pebbles up to $\frac{1}{8}$-inch diameter. These beds assigned to Turkey Ridge sandstone as equal to numbers 1, 2 and 3 on opposite limb of syncline. All barren so far in this section	130
9.	Concealed along road for 0.2 mile	?
10.	At road fork at Goodville. Small cuts. Sandstone, olive-gray, massive to flaggy, fairly coarse and partly hidden	100
11.	Continuous with 10. Sandstone, platy, gray, brown-weathering, poor showing; probable fault south of here	10
12.	Continuing around bend in road. Mexico sandstone again seen, re-introduced in section by faulting, all beds barren. Showing poor in weathered bank.	
13.	Concealed to next turn north in road at secondary road from south; cuts. Sandstone, massive to flaggy, breaking up to large, irregular blocks; gray to olive-gray, dark-brown-weathering, coarse. Showings poor, appears to be repetition of beds to south through overturned fold.	
14.	Concealed to next road from west. Probably platy sandstone.	
15.	Turkey Ridge sandstone again exposed. Massive, gray to olive-gray, brown-weathering. coarse. Here, as this member rises again, it produces small ridge.	
16.	Concealed, probably all platy sandstone to next cross-road. Massive sandstone float seems to imply Turkey Ridge member once more rising.	
17.	At cross-roads, road cuts at southwest corner. Shale, black, fissile, somewhat finely arenaceous. Evidently more nearly conventional type of Marcellus shale. Shows also in small, abandoned quarry*	18
18.	Concealed across brook and at road side	45
19.	Shale as at 17	8
20.	Concealed	15
21.	Shale as at 17, but platy rather than fissile. The total lower Marcellus black shale (Shamokin) appears here to be about 116 feet thick. It passes into a sheared, unsymmetrical fold which brings up the Onondaga (Selinsgrove) non-cherty limestone.	
22.	Sandstone, platy, friable or breaking into rectangular bits, pepper and salt to buff color, brown, or rusty-weathering, medium coarse, weak, crushed; in sharp contact with underlying limestone, but merges upward with the lower Marcellus (Shamokin) black shale	1′ 4″
23.	Onondaga (Selinsgrove) limestone. Massive beds alternate with platy or shaly, very dark, weathering light, somewhat sheared. No chert, but sometimes tiny quartz crystals abundant; nodules and stylolites. Base hidden. Exposed	4

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* N. B. The Marcellus shale throughout this region appears to lack slaty cleavage and concretions observable elsewhere. Likewise there are no sooty beds of the Union Springs type. Being also barren, it suggests the Chittenango shale of New York.

		Feet
24.	Limestone passes down into limy, dark shale north along road. This shale weathers greenish and is assigned to the Needmore member. Occasional bands of good limestone are present. Fossils in greenish shale 32 feet below top. Base hidden	42
25.	Oriskany (Shriver?) chert, light colored, below Onondaga limestone, but none surely in place.	

K. Lycoming County, Larrys Creek

In this succession, only the Portage group is included. The section shows the passage downward from the sandstones through green Brallier, gray Harrell and finally black Burket shales, to the Tully limestone. The limestone is here exposed in its thickest known section in Pennsylvania. The section follows the line of the New York Central Railroad and the bank of the Susquehanna River south from Larrys Creek depot on the Williamsport quadrangle.

1.	South from Larrys Creek depot (this is the building nearest the creek on the map), 600 feet cut; Trimmers Rock flaggy sandstone plus considerable Brallier type shale. This shale and platy sandstone dominate along the track southward for 400 feet	277
2.	Partly concealed; probably similar to 1	?
3.	Similar to 1, but flaggier, less shale and some heavy sandstone beds in upper part. *Pteridichnites* and woody fragments present in shale	165
4.	Concealed, gully with ancient, abandoned kiln. Probably there is faulting here. Approximate thickness	75
5.	Shale, platy to fissile, with a few sandstone lenses, dark gray to gray-green, *Pteridichnites*. Evidently these beds are Brallier but partake of Trimmers Rock lithology in a measure	12
6.	Concealed. Possibly some faulting here	75
7.	Tully. Uppermost beds shale, gray to greenish, limy with a few arenaceous beds, corals plentiful. Below, passes into platy limestone. Considerably distorted as rises in broad, low anticline whose south limb passes under valley with brook from Martins School. This unit may be readily mistaken at first glance for the Helderberg. Fossils very rare except at top, in about 5 to 10 feet of shaly limestone. In the south limb an *Atrypa* and coral zone noted about 5 feet below top	145
8.	Concealed in gully. Thickness	?
9.	Beginning long cut. Brallier shale again comes down to track level; sandy to fissile and some sandstone lenses, olive-gray. One massive sandstone bed about twenty feet above base. Large fucoids. Exposed	50
10.	Fault zone. At least two faults here, but aggregate movement probably not greater than a few feet.	
11.	Number 9 lothology repeats south of fault zone, but lower in sequence	98
12.	Harrell shale conformable with Brallier of 11; a little sandstone, platy to shaly, gray, grows blacker below, shalier; fissile forty feet below top. The upper forty feet are therefore assigned on lithology chiefly to the Harrell; the remaining sixty-odd feet to the Burket. The black Burket shale is considerably distorted and faulted. Approximately.	100
13.	Continuing south. Tully limestone again rises in a second, and sharper, anticline; Burket and Tully in normal contact at north end of north limb where a fault cuts the lower Burket. Base of Tully hidden, minimum thickness	240

L. Monroe County, Brodhead Creek

Section L has many concealed gaps, but nevertheless records features of the Devonian that are all-important in eastern Pennsylvania. Thus, the Onondaga group may be observed where it consists of the Esopus shale and the cherty Buttermilk Falls limestone. The most fossiliferous Marcellus in the State, the Laurens member with its Tully elements at the base of the Trimmers Rock sandstone, the type region for the Analomink red shale, all lie in this section. The section starts south of Stroudsburg and runs north along Brodhead Creek valley to Analomink. It is in the Delaware Water Gap and Bushkill quadrangles.

		Feet
1.	Base of Godfrey Ridge, south of Stroudsburg on Highway 611. Onondaga (Buttermilk Falls) cherty limestone in small exposure. This overlies the Esopus which is well exposed south on the ridge in road cuts and is there fossiliferous with an Onondaga fauna.	
2.	Concealed across flat into Stroudsburg.	
3.	At Erie (formerly New York, Susquehanna and Western) R. R. station at Stroudsburg; cut. Onondaga group (Buttermilk Falls limestone) exposed along south side of track in cut; non-cherty, fossiliferous; dips rather steeply north, top hidden.	
4.	Bed of McMichaels Creek south edge of Stroudsburg business center and about 100 yards north from 3. Transitional, Onondaga-Marcellus contact, the dark-gray limestone passing upward into black shale with light-colored, limy bands. Dip flattens northward.	
5.	Concealed through Stroudsburg.	
6.	Quarry north side of Stroudsburg west from Highway 90; Marcellus black shale, slaty cleavage, small siderite (?) concretions; highly fossiliferous throughout. Exposed	35
7.	Concealed north along Highway 90.	
8.	Reservoir Hill north of Stroudsburg. No exposures, but black, Marcellus shale excavated.	
9.	1.4 mile north of 6 on Highway 90, opposite school (Bushkill quadrangle) small cuts. Marcellus black shale, some finely arenaceous, weathered, sheared beds.	
10.	0.6 miles north of 9, on Highway 90. Abandoned quarry east of road. Marcellus black shale, more or less banded, the banding showing best on weathered faces, sheared, fossiliferous as at 6.	
11.	0.7 miles north of 9, small cuts along Highway 90. Black shale, barren. Passes immediately up into gray sandstone, so that the presumption is that the shale is approximately the top of the Marcellus if not actually lower Mahantango (Skaneateles). The Marcellus thus crops out along a horizontal distance of 2.7 miles perpendicular to the strike. However, all exposures are small, and some very poor. Calculating the thickness it appears to be of the order of 800 to 900 feet.	
12.	Mahantango formation. Sandstone, fine, gray, partly hidden, overlain by dark-gray to black, very fine-grained and finely laminated sandstone weathering brown or light-gray; "*Spirifer*" *mucronatus*, etc., present. This is the lowest Mahantango faunule ("Hamilton" facies). These lower Mahantango beds have few fossils, until about 165 feet above base, where a fairly abundant faunule assigned to the Skaneateles faunal facies appears in a five-foot bed	165

		Feet
13.	Concealed	30
14.	Highway 90, jog in road southeast of knoll two miles from Stroudsburg. Mahantango sandstone, dark-gray, weathering lighter, fairly coarse; quite fossiliferous	?
15.	Concealed save for small showings like 14	35
16.	Mahantango sandstone similar to lower beds but finer, sheared at right angles to bedding; barren	36
17.	Concealed to Centerfield coral reef, save for insignificant showings. No fossils seen in place, attitude dubious. Thickness.	?
18.	Centerfield coral reef. Shaly matrix, gray-brown, somewhat sandy, full of great variety of fossils; lower 3-4 feet carries relatively few fossils; remainder honeycombed in weathered parts, although fresh rock massive and limy, brown shale. Fossils well-preserved and not much battered or comminuted. The reef is not a coquinite. Continues up into brown, rather sandy shale, top hidden. Marks approximate base of Ludlowville	18
19.	Concealed; brings section to point where road nears creek..	7
20.	Sandstone, dark-gray, sheared, much like 14, partly hidden..	17
21.	Continuous with 20. Similar but finer grained with large storm rollers. This carries section around point almost to first brook at house. Nearly barren	15
22.	Concealed	260
23.	Cuts, several small exposures along west side road. Sandstone, gray, medium to fine-grained, fossiliferous	13
24.	Concealed for about 0.15 miles	
25.	Road west to Bartonsville. North side of road, ledges of Mahantango sandstone, dark-gray, brown-weathering, rather coarse	?
26.	Concealed to bridge over Brodhead Creek. Ledges under bridge and below it carry highest Hamilton faunule found in this section. Turning east and crossing the valley of Brodhead Creek and the R. R., Highway 90 intersects Highway 190 a little north of east from 26 and a trifle higher in section, though the precise difference is indeterminate.	
27.	Intersection of Highways 90 and 190; cuts. Trimmers Rock sandstone; fairly abundant fossils, including at base Tully elements and correlated with the Laurens member of New York State. The detailed sequence is:	

		Feet
D.	Top, light-gray, hard, flaggy sandstone, shale above	12
C.	Partly hidden, shaly sandstone	20
B.	Brown shaly sandstone	28
A.	Base; gray, hard sandstone	15

A, B, and D are fossiliferous, the upper fossils Ithaca, Tully below. Exposures continue north for about 200 feet.

28.	Concealed for 4.0 miles north along Highway 190.	
29.	Cuts east side of road near Analomink switch tower on Delaware, Lackawanna and Western Railroad. Road makes S-turn. Trimmers Rock sandstones, platy, hard, some heavy beds, dark-gray	48
30.	Concealed for about 1500 yards.	
31.	Trimmers Rock sandstone, heavy, dark-gray to slightly olive, light-gray-weathering, rather coarse	22

		Feet
32.	Partly concealed northward. Scattered exposures like 32 for ½ mile to turn or road east at Analomink, where the lithology changes to cross-bedded, gray to greenish-gray flags and heavy sandstones suggestive of Delaware River flags. These beds are overlain by the first red in this section, the Analomink red shale (type locality).	

M. Northumberland County, South Danville Section

Section M is interesting in that it includes the locality and exposure where the Tully was first fully authenticated in Pennsylvania. There are presented here the Hamilton-Tully-Burket-Upper Portage relations and sequence and the Portage-Catskill transition as typically as any central Pennsylvania sequence. The Portage is mostly sandstone, showing displacement of the shaly facies eastward. The sequence runs from South Danville depot on the Pennsylvania Railroad southeastward along Highway 54 and the railroad and river bank. It is on the Shamokin quadrangle.

		Feet
1.	Marcellus shale, black, fissile, sharply separated from overlying beds. Continuous to small brook opposite depot, but base hidden. Pencil fracture	340
2.	Road cuts. Mahantango shale little exposed, finely arenaceous to shaly sandstone, gray, brown-weathering, sheared and jointed. Calculated thickness This carries section to within 225 feet of brook 0.6 mile above bridge. Lower beds appear to be nearly barren save for some plant stems. Top concealed. Mahantango facies fauna about 100 feet below top. Some black shale in midst suggests recurrent Marcellus conditions.	810
3.	Continuing southeast along highway. Mahantango sandstone, gray, fine-grained to shaly, chunky fracture; *Tropidoleptus* and *Ambocoelia* abundant	87
4.	At brook, secondary road up valley exposes dark, chunky, shaly sandstone with Mahantango facies fauna; *Taonurus* common. Beds about equal top of 3.	
5.	Concealed in valley	75
6.	Mahantango sandstone, fine, dense to shaly, very dark gray and a little dark shale in lower 3 to 4 feet, but sandier above. *Vitulina* in dark shale in upper part implies top of Hamilton group (Moscow faunal facies)	47
7.	Tully limestone, shaly, gray, sheared; fossiliferous. *Hypothyridina* present, along with other characteristic Tully fossils. This is the first locality at which Tully was fully established in Pennsylvania	10
8.	Tully shale, limy, gray, nearly barren	13
9.	Burket shale, fissile, black, weathering dark gray, intergrades with 8 and apparently barren	78
10.	Sandstone, shaly, dark, much like 9, but pencilly fracture and weathers dull brown and presumably is of Burket or Harrel age; barren	147
11.	Trimmers Rock sandstone, flaggy to platy and some dark shaly portions; gray, in lower part, barren save for crinoid "joints," but fossiliferous zones upward, thus: Zone 1, 95 feet above base: *Aulopora* Zone 2, 163 feet above base: Ithaca faunule Zone 3, 280 feet above base: crinoid "joints" Zone 4, 310 feet above base: coquinite	

		Feet
	Top concealed. Carries section to small brook opposite State Hospital. Fossils at the top as exposed. Zone 5, 430 feet above base: Ithaca faunule	453
12.	Concealed interval to near top of first hill southeast of 11; cuts, slumped.	
13.	Interbedded light, olive-gray and buff sandstone and shale weathering light brown or rusty. Shale dominates. Two to 3-foot red shale in lowest part followed by faunule with "*Spirifer*" *mesacostalis* and "*S.*" *mesatrialis* abundant	125
14.	0.1 mile beyond 12 at cross-roads. Small showing of red beds presumably in place. From here on red beds dominate in intermittent showings to bridge over Roaring Creek.	

N. Perry County, Juniata Valley East

Section N is the most entire and in many respects the finest Devonian sequence to be seen anywhere in Pennsylvania. Starting well up in the Catskill, a complete sequence is recorded down to and including the top of the Helderberg. The various contacts, transitions, and faunal features are unusually good, and for structure, none of our Devonian sequences better illustrate so clearly both folding and faulting. This, of course, is Section 4, Figure 88, here recorded in full detail. This section starts at the first exposures along Highway 22 north of Amity Hall and continues up the east bank of the Juniata River to Half Falls Mountain. All exposures are in the New Bloomfield quadrangle.

The first exposure is about ¼ mile north of the highway intersection at Amity Hall. Although this section starts in the Catskill, it should be observed that the beds of this facies continue south far up the north slope of Peters Mountain at the confluence of the Susquehanna and Juniata Rivers.

1.	At rise above river flat ¼ mile north from Amity Hall. Catskill sandstone, red, interbedded with thin beds of gray to brown sandstone, sheared	15
2.	Sandstone, flaggy, gray to brown, weathering rusty, directly underlies 1 in small, abandoned quarry opened on a small anticline	16
3.	Sandstone, shaly to flaggy, brown; underlies 2 and overlies 4.	12
4.	Sandstone, fairly massive, brown to gray	3
5.	Concealed in gully	3-4
6.	Sandstone, quite massive, forms small cliff at north side of gully; grayish, brown-weathering; base shaly	15
	The above units repeat in the north limb of the anticline. Carries section several hundred feet north to road east at first brook.	
7.	Cliff, south side of first brook at secondary road from east. Catskill sandstone, shaly with shale partings, red. Precise equivalence to beds to south uncertain	12
8.	Continuous with 7, similar but shalier	27
9.	Sandstone fairly massive, greenish, brown-weathering	½
10.	Shale, fissile, greenish, sheared, grades into 9	½
11.	Sandstone, shaly, red, some brown sandstone bands	8
12.	Shale, greenish with 3-inch sandstone at top	2/3
13.	Shale, some sandy beds, red	40

		Feet
14.	Shale, greenish-yellow, double band separated by a red shale parting	2
15.	Shale, some sandstone bands, red	30
16.	Concealed for about 320 feet.	
17.	Continuation downward of 15. Sandstone, shaly, red. This unit lies nearly flat for several hundreds of feet. In it may be seen a gray sandstone lens north of the axis of a small anticlinal fold. These beds contain plant fragments. Brownish shale lenses appear also and have the aspect of cross-sections of channel deposits. The non-red beds are in unconformable relations with the underlying red	65
18.	In this interval the beds repeat themselves, first dipping gently northward, and then are thrown into a series of small but close folds. The structures may be followed by observing certain thin, olive-brown shale bands which rise and fall with the folds. These are probably lenticular, or extend for only a relatively small distance, and are unreliable for key beds save very locally	
19.	Concealed	20
20.	Catskill sandstone, shaly, dark-gray to nearly black, brown-weathering. Abnormal color is due to contact with 21. No doubt there is faulting here, but the extent is unobtainable, though it is inferred to be of the order of some tens of feet.	10
21.	Triassic "diabase" dike. Finely crystalline suggesting a diorite. Nearly black, weathers to buff-yellow or rusty soil. As it here appears to run nearly parallel to the bedding it is perhaps more truly a sill locally. This is believed to be the same dike that has been intermittently "picked up" across Perry County south into Cumberland where it produces Ironstone Ridge	25
22.	Catskill shale, dark, buff-weathering; much sheared and baked. This and 20 show considerable alteration through contact metamorphism with the dike, 21	3
23.	Shale, sandy, massive, red	5
24.	Shale, fissile, red, partly hidden, folded	40-50
25.	Shale, sandy, brown; crumpled red shale interbedded. Approximately	35
26.	Shale, brown, No. 25, repeats through relatively close folding and probably in part equals 18 lithologic sequence, including local key beds	6
27.	Shale, somewhat sandy, greenish; calcareous shell fragments, presumably an incursion of the Chemung sea	1
28.	Shale, sandy, partly sub-massive, but dominantly fissile, red, brown-weathering	65
29.	Shale, fissile, yellow-green	1/3
30.	Shale and sandstone, red	4
31.	Shale, fissile, yellow-green	1
32.	Shale, some sandy beds, red	20
33.	Concealed	65
34.	Repetition of 32 in fold; small thrust fault here	
35.	Concealed. Approximately	210
36.	Shale, quite fissile, it tends to form "slate pencils," some massive sandstone bands, gray to brown, weathering dark brown or rusty	25
37.	Similar to 36, without sandstones	9

		Feet
38.	Sandstone, massive, red to red-brown; some interbedded brown shale like 36 and a little green shale with fossils believed to be Chemung	23
39.	Concealed	130
40.	Sandstone and shale interbedded, red	15
41.	Concealed	115
42.	Shale, a few massive sandstone bands; brown, weathering darker, resembles 36, whch it may equal as structure in concealed intervals unknown	20
43.	Repetition of 42 by folding; then red sandstone and shale. Probable faulting. Near top of these red beds is conglomeratic band with white quartz pebbles	30
44.	Sandstone, massive, gray, grading laterally into red	3
45.	Sandstone, flaggy, brown	3
46.	Shale, like 43	15
47.	Sandstone, like 45	1½
48.	Shale, sandy, red; grows massive near base	13
49.	Shale, like 45, but somewhat browner	12
50.	Sandstone, shaly, red; some greenish bands with Chemung fossils	18
51.	Sandstone, massive, with interbedded shale, brown. Lower half massive	12
52.	Shale, sandy, alternating red and green. Partly concealed..	10
53.	Partly hidden, probably equals 52, continued downward....	30
54.	Shale, brown, pencil fracture	10
55.	Sandstone, massive red	7
56.	Shale, like 54, but with massive 3-foot sandstone in middle...	16
57.	Shale and sandstone, alternating, red	8
58.	Shale, greenish, barren	3
59.	Sandstone and shale, red	35
60.	Sandstone and shale, brownish-gray, partly hidden	30
61.	Concealed; valley occupied by secondary road about ½ mile south of point opposite Losh Run Station	110
62.	Sandstone, somewhat shaly, chocolate-brown, fossiliferous with what is thought to be Parkhead faunule	25
63.	Partly concealed, a few small exposures of gray or greenish shale and shaly sandstone and chocolate-tinted beds	123
64.	Sandstone, shaly to fissile, gray, some chocolate-brown interbeds, brown-weathering. Base rather massive	60
65.	Shale, fissile, olive-gray to greenish, weathering dark brown, some greenish bands; fossiliferous, Ithaca faunule. These beds belong in upper Trimmers Rock sandstone	75
66.	Sandstone similar to 65, but more massive	30
67.	Shale, with sandy beds, chocolate-brown	20
68.	Shale and sandstone interbedded, brownish. This is at south end of high cut cliff opposite Losh Run	10
69.	Shale, arenaceous, fissile, gray, brown-weathering; olive-gray sandstone at base. Crinoid "joint" zone 10 feet below top..	15
70.	Shale, with sandstone lenses, chocolate-brown	8
71.	Shale, quite sandy to massive, some finely laminated, olive sandstone lenses, a few gray sandstone lenses and a little olive shale, otherwise chocolate; bryozoa and fragmentary brachiopods at top, crinoid "joint" zones 5 and 10 feet below top	28

		Feet
72.	Sandstone, even-bedded, olive-gray to chocolate; beds appear to change color laterally and contain two small lenses of comminuted shell fragments 5 and 6 feet above base	35
73.	Sandstone, very massive, gray to brown; large crinoid "joints" to 1.5 inches in diameter and shell fragments at base	2
74.	Sandstone, shaly, chocolate, contorted locally, perhaps concretionary or storm rollers. Highest point in cliff	6
75.	Sandstone similar to 72. Scattered crinoid "joints" in upper 5 to 10 feet; lenses of comminuted fossils occasional, including bryozoa, etc.	125-130
76.	Sandstone, massive, olive-gray	6
77.	Sandstone, flaggy to shaly, some massive bands, olive-gray, brown-weathering or rusty, may weather light-gray locally; coquinite lenses; fossils chiefly in lower third in lenses to 1 inch thick	90
78.	Sandstone, finely laminated, flaggy, dark-gray. Bryozoan band 2 feet below top	30
79.	Sandstone, quite massive, zone of 2-foot storm rollers, gray, brown-weathering. This is at deep gully with dry steam opposite Losh Run station	28
80.	Sandstone, flaggy, gray to brown, weathering in brown, coquinite 4 feet above base	25
81.	Sandstone similar to 78	15
82.	Sandstone, massive, brown	2½
83.	Sandstone, shaly, weak, gray, weathering darker gray or rusty; crinkled; fossils at top	150
84.	Sandstone, massive, brown	18
85.	Sandstone, flaggy, brown This carries section north to point opposite Losh Run.	25
86.	Concealed in valley	?
87.	Shale, sandy, dark-gray, weathering brown, passes downward into sandstone. This is the Losh Run shale, type locality. Very fossiliferous, *Reticularia laevis* zone. The upper 10 to 15 feet are the true Losh Run. Lower part highly contorted and thickness indeterminate. Minimum, estimated thickness:	100
88.	Shale, sandy and much like 87 but finer grain and thinner bedding to fissile. Some beds platy. These beds are best assigned to the Brallier	100
89.	Sandstone with much shale, some flaggy to nearly massive beds; a massive 1-foot sandstone at top; gray, brown-weathering, lower portion gray. Evidently equivalent to Harrell shale, but sandy, as here and in lower beds a Naples fauna obtains.	155
90.	Sandstone, massive, brown	4
91.	Shale, somewhat sandy, fissile, pencil cleavage, weathers to soft, loose slope, black when fresh. *Styliolina* and *Buchiola* present. This is Burket and unusually thick	200
92.	Shale, fissile, gray with thin limestone bands or nodular zones. Tully fauna abundant	10
93.	Shale, gray, fossiliferous, *Vitulina* zone marking top of Hamilton. Contact with 92 sharp	15
94.	Concealed, valley with short, secondary road below ferry of map (New Bloomfield quadrangle)	65
95.	Shale, similar to 93, but more fissile, dark-gray	130
96.	Sandstone, massive, heavy-bedded, gray, brown-weathering, medium-grained. This marks top of Montebello sandstone..	33

		Feet
97.	Sandstone, flaggy to shaly, gray	14
98.	Shale, weak, fissile, brown	20
99.	Sandstone, massive to flaggy, gray, weathering brown, partly concealed. Approximately	30
100.	Shale, similar to 98	9
101.	Shale and sandstone interbedded similar to 98 and 99	35
102.	Sandstone, massive to flaggy, light gray, weathering same, but with iron-stain, a few scattered pebbles; exposed in small anticline	23
103.	Concealed, valley east at turn of road. Shale and sandstone appear to underlie this as 101 and 102 go down and rise again.	
104.	Concealed for .2 miles. Presumably the upper Hamilton shales underlie this area.	
105.	First ridge south of Half Falls Mountain. Sandstone, massive to flaggy, gray, brown-weathering, evidently same as at 102, etc., or a little lower. This is part of the main body of the Montebello sandstone	8-10
106.	Shale, sandy, gray-brown, weathering dark-brown to rusty-black; casts of shells at base	7
107.	Montebello sandstone, massive. This member, largely hidden along highway, rises in ridge. From it a great talus slope falls off northward from scarp near ridge top, marking the Perry County fault. Fossiliferous here. Estimated thickness.	880
108.	Concealed along road	?
109.	South slope of Half Falls Mountain. Quarry. Section here:	
	Top: Marcellus shale, black, fissile, weathers brown	20+
	Base: Onondaga (Selinsgrove) limestone, black, slaty, fairly massive, base hidden, exposed	30
	The disconformity between the shale and the limestone is marked by a thin band of soft, ferrugious sandstone 2 to 3 inches thick	
110.	On highway below the quarry. Oriskany pebbly sandstone and conglomerate exposed dipping south as south limb of Half Falls Mountain anticline. No intervening shale between the limestone and Oriskany shows; presume some present, but very thin as limestone exposed close above Oriskany on north limb of anticline in woods and mountain slope.	
111.	Gully at axis of anticline, abandoned quarry. Topmost beds of Helderberg limestone, New Scotland exposed.	

O. Perry County, Little Juniata Creek Section

Partly supplementary to section N in that it runs higher into the Catskill, this section is introduced primarily to show the monotony of the continental facies in central Pennsylvania. The succession has been drawn from Duncannon along Little Juniata Creek and Highway 274 and the Susquehanna River and Western Railroad northwestward on the New Bloomfield quadrangle.

1.	Shale, fissile, with sandstone bands, dark red	15
2.	Concealed	30
3.	Similar to 1	2
4.	Sandstone, massive to platy, red	45
5.	Concealed	17
6.	Sandstone, similar to 4	8-10
7.	Concealed	18

		Feet
8.	Repetition of 4 in small, flat folds.	
9.	Shale, fissile to platy, red-brown	8
10.	Sandstone, massive to platy, red to red-brown or dark-red..	30
11.	Concealed	110
12.	Sandstone, massive, red-brown; partly hidden	22
13.	Concealed	12
14.	Sandstone, massive to flaggy, gray, brown-weathering, some gray-green shale near top; partly hidden	15
15.	Shale and sandstone, red; partly hidden	10
16.	Shale and sandstone, sub-massive to fissile.	40
17.	Sandstone, fairly massive, green turning brown above, brown-weathering; doubtful plant fragments	6
18.	Concealed, probably red sandstone and shale	14
19.	Shale, fissile to sandy, red	12
20.	Sandstone, massive to flaggy, growing shaly at top, red-brown	15
21.	Concealed	105
22.	Sandstone, massive, red	6
23.	Sandstone, shaly, red	2
24.	Sandstone, massive, gray-green in small, abandoned and overgrown quarry	1
25.	Sandstone, massive, red, partly hidden in quarry	15
26.	Shale, fissile, red	15
27.	Concealed	125
28.	Sandstone, massive, red	2
29.	Concealed	120
30.	Shale, fissile, with some sandstone bands, red	30
31.	Concealed	11
32.	Sandstone, massive to platy, red	25
33.	Concealed	120
34.	Sandstone, massive, red and gray alternating, probably some platy beds; partly hidden	100
35.	Sandstone, very massive, gray to olive-gray	35
36.	Shale, fissile, chunky fracture, somewhat sandy, greenish....	6
37.	Sandstone, fairly massive, greenish	7
38.	Sandstone, massive to platy, red-brown	20
39.	Partly concealed, probably similar to 38	56
40.	Shale, fissile to sandy and platy, red	7
41.	Cut bank east of road opposite junction with first road south, north of Duncannon	10
42.	Shale, fissile, sandy at base, red to chocolate; partly hidden.	12
43.	Sandstone, fairly massive, gray-brown, brown-weathering..	25
44.	Shale, sandy at top, grading down into 43, gray, weathering brown or gray. Doubtful plant fragments at top. Exposure in small anticline in quarry to east. This unit repeats to northwest	4
45.	Concealed	30
46.	Sandstone, massive, reddish to chocolate-brown. Shows in bed of brook at bridge	6-7
47.	Shale, fissile to sandy and flaggy, red. Crops out at side of creek	12
48.	Sandstone, flaggy to sub-massive, red	2
49.	Sandstone, massive, brown	20

		Feet
50.	Shale, sandy, fissile, gray-green	4
51.	Sandstone, massive to flaggy, gray; plant stems	30
52.	Shale, fissile, slightly arenaceous, red	20
53.	Sandstone, flaggy to shaly, red-brown with some gray beds. Lower 25 feet quite heavy	45
54.	Concealed	56
55.	Sandstone, massive to shaly, red; partly hidden	8-10
56.	Shale, fissile to sandy, dark-red	15
57.	Sandstone, massive, brown to red-brown; makes small rips in creek	10
58.	Shale, fissile, dark-red; some sandstone bands, red-brown	18
59.	Concealed	34
60.	Sandstone, massive to flaggy, olive-brown to olive-gray	2
61.	Concealed	62
62.	Sandstone, flaggy, red-brown	2
63.	Concealed	12
64.	Sandstone, similar to 62, but platy	5
65.	Concealed to turn in road at "C" of "Creek"	?
66.	Shale, very weak and fissile, gray-green, weathers brown and appears to pass down into shaly sandstone	21
67.	Shale, fissile, red	2
68.	Sandstone, platy to shaly, gray-brown, brown-weathering	24
69.	Concealed	4
70.	Sandstone, massive to platy and some shaly beds, olive-gray to brownish-gray, brown-weathering, plant stems	12
71.	Concealed in valley save for outcrops under R. R. bridge	70
72.	Shale, sandy, red, mostly hidden	25-35
73.	Shale, fissile, greenish, brown-weathering	5
74.	Sandstone, flaggy, greenish	12
75.	Shale, similar to 73	3
76.	Sandstone and shale, massive below, red	5
77.	Shale, similar to 73	3
78.	Shale, fissile to sandy and platy, dark-red	36
79.	Sandstone, flaggy to sub-massive, red	8
80.	Shale, fissile, greenish, like 73	2
81.	Shale, fissile, red	40
82.	Sandstone, very massive, brown; rips in creek	18
83.	Shale, fissile, red; partly hidden	50-60
84.	Sandstone, flaggy to sub-massive, red-brown. Carries section to point opposite brook from west below Kings Mill	20
85.	Concealed	48
86.	Sandstone, massive, red-brown; partly hidden	10
87.	Concealed	62
88.	Sandstone, massive, brown; partly hidden	8-10
89.	Concealed	10
90.	Shale, sandy, gray, brown-weathering; partly hidden	10
91.	Shale, fissile, red-brown	2
92.	Sandstone, sub-massive, red-brown	6
93.	Sandstone, shaly to platy, brown or gray-brown; partly hidden	10
94.	Concealed	57

		Feet
95.	Sandstone, massive to shaly, purplish; in secondary road from southeast at Kings Mill	5
96.	Concealed	2
97.	Sandstone, sub-massive to platy, gray, weathers brown; partly hidden	20
98.	Concealed	104
99.	Sandstone, platy, gray, brown weathering	?
100.	Concealed	100
101.	Small, non-descript exposures in gutter	?
102.	Along west bank of creek. Sandstone, fairly massive, hard, almost cherty, gray, contorted	15
103.	Concealed	15
104.	Sandstone, massive, red-brown	10
105.	Sandstone, flaggy, gray with interbedded brown beds; ripple marks. Forms steep cliff along creek, fine exposure	45
106.	Concealed	20
107.	Sandstone, massive, grayish	15
108.	Sandstone, rather massive to flaggy, chocolate; base hidden.	20
109.	Section continues along R. R. northwestward from Kings Mill. Shale, friable and chunky, reddish-chocolate; some sandstone bands	18
110.	Sandstone, massive, purplish-red; partly hidden	5
111.	Concealed	15
112.	Shale, purplish	5
113.	Concealed	12
114.	At road junction from west. Sandstone, shale, gray-green, ripple marks; some chocolate beds	13
115.	Concealed in valley of road from west	15
116.	Continuing along R. R. and creek. Similar to 110	5
117.	Concealed	20
118.	Shale, sandy, gray-brown	5
119.	Concealed	25
120.	Shale, reddish-chocolate. Probably equals 110 per structure.	20
121.	Section continues north on R. R. Shale, weak, brown	3
122.	Beyond crossing of R. R. and secondary road at Sulphur Springs. Sandstone, massive, hard, brown	4
123.	Sandstone, flaggy to slightly shaly, dark-red, almost purple, breaks into chunks	10
124.	Sandstone, shaly, similar to 123, but more shale and purple-red	18
125.	Shale, sandy, weak, brown to purplish. Seen in small cliff of channel abandoned by stream diverted by R. R. fill	20
126.	Concealed	15
127.	Shale, fissile, gray; partly hidden	30
	N. B. There may be some repetition here, as structure uncertain.	
128.	Shale, similar to 127, but reddish-chocolate	3
129.	Shale, similar to 127	4
130.	Concealed	35
131.	Sandstone, shaly to fissile, but some beds massive, gray	10

		Feet
132.	Shale, sandy, fissile, reddish-chocolate	50
133.	Sandstone, massive to shaly or splintery, gray; reddish weather stain deceptive; partly hidden	45
134.	Sandstone, fissile to massive, gray, weathers rusty. Small outcrop at "S" of "Sulphur"	?

Carries section to vicinity of abandoned factory near Sulphur Springs. A long concealed interval follows the creek, and the next succession of beds is below the Catskill facies and shows marine fossils assigned to the Portage group. Although this section passes through Kings Mill, it fails to include the fossiliferous, white Kings Mill sandstone which occurs some 500 feet above the lowest Catskill red beds. This anomaly is explained by the fact that the sandstone occupies one of the several concealed intervals in the section. It occupies about the position of number 103.

CHAPTER X.

GEOLOGIC HISTORY

In the preceding chapters of this account, my co-workers and I have described the Devonian system in Pennsylvania. Professor Swartz has told about the Helderberg group; Dr. Cleaves has given an account of the Oriskany. I have treated, first the Middle, then the Upper Devonian marine formations, and finally the Catskill continental facies. Evidently, the several marine formations and groups of formations have been deposited in a chronologic sequence, an orderly succession, from the oldest, the Helderberg limestones, through the youngest, the Conewango beds. Of contemporaneous deposition with many of them are the continental sediments of the Catskill. The correlation charts show succession and equivalence. But the many units differ markedly in lithology and fossils. Some of the so-nominated ''formations'' pass into others either laterally or vertically. More are separated from over- and underlying units by disconformities, ''breaks'' in the sedimentary sequence. These changes and differences should be accountable for by modifications of environment during the intervals of deposition, by the nature of their place of origin, by organic evolutionary progress. By treating the Devonian period from the view point of history, or the chronologic sequence of its events, it is possible to account for many of these changes that have transpired during the deposition of the rocks of the Devonian system. Like human history, the happenings are not all of equal importance, nor are they equally well known. Parts of the record are gone. We may only surmise what went on in these ''lost intervals''.

The Devonian Environment

During the Paleozoic era, of which the Devonian makes up the fourth of its seven periods, the region we now call North America appears to have been quite different from what it is today. A continent there was, but its outlines scarcely resembled the present configuration. During the Paleozoic, mountain systems grew and were worn away, large parts of the interior of North America were flooded by vast bodies of salt water, termed epeiric seas. Along the eastern margin of Palamerica there extended a land mass. Its western shore approximated, during much of the era, that part of the continent called today the Piedmont. How far east the land may have reached is problematical. Estimates vary from only a few hundred miles to a vast land, a land now largely incorporated in the continent of Europe. Such a grotesque-sounding statement is based on the hypothesis that North America and Europe were once united as a single landmass which split asunder, the respective fragments drifting apart, leaving between a wide, water-filled rift, the Atlantic Ocean. Evidences of the truth or fallacy of this theory are beyond the limits of this discussion. Whatever were the eastward limits of Appalachia, it is conjectured from its existing remnants to have been a region of crystalline rocks, granite, gneiss, schist. At times it under-went intervals of uplift and mountain building; again it seems to have been worn low through ages of weathering and erosion. The western shore line was not fixed, but shifted back and forth, now farther east, now farther west. It had its bays and peninsulas, beaches and deltas.

From this ancient Appalachia, rivers flowed westward into the epeiric sea, the reverse of the courses of the rivers of our present-day eastern seaboard which drain into the Atlantic. I have described evidence for the presence of several of the ancient streams of Appalachia, evidence taken from the recognition of old deltas which those streams of long ago laid down along its western coast. But the deltas embrace only a small fraction of the waste of the land which went into the interior sea. Most of the thousands of feet of Paleozoic clastic sedimentary rocks now known probably came from Appalachia. The formations of sandstone and shale are observed usually to be thickest in the east, that is, near the ancient coast, and to thin gradually westward, away from the shore. Yet despite vast thicknesses, it is demonstrable that much of the material composing this great wedge of rock was laid down in shallow water. Cracked muds of ancient ''flats'' bespeak exposure to sun and air. Ripple-marked aqueous sediments can originate only in water shallow enough for waves or currents to stir the bottom. Many of the fossils are remains of animals that dwelt in relatively clear, shallow, well-lighted water. How, we may ask, could so much of this vast pile of rocky layers have formed in shallow water? How may a shallow sea bottom constantly receive layers of sediment, yet remain submerged?

The Appalachian geosyncline. The answer is found in what the geologists call a geosyncline. This is a concept of simply a long, narrow, downwarped part of the earth's crust occupied by a sea, a shallow trough adjacent to a land mass. Into it detritus from the land is poured by the rivers. Tides and currents catch up the pebbles, sands and muds and sweep them along the coast or out to sea, spreading them in ever thinning layers away from the source of supply, the land. Studies in geophysics and earthquake lore teach that beneath the solid crust of the earth there is a ''fluid substratum''. Though a fluid, it is not a mobile liquid; it is highly rigid. This substratum, the asthenosphere, tends to yield and flow under heavy, long-applied, slow pressure. If an ever increasing weight be steadily added to an appreciable area of the crust, accumulating downward pressure must be exerted upon the substratum. It, therefore, tends to flow away from such a region of great to areas of lesser, downward pressure. Such a shift takes place beneath the accumlating load of sediment in a geosyncline. Therefore, as the sediments accumulate, layer upon layer in shallow water, the substratum migrates gradually out from under, the bottom slowly sinks, and the water may remain at essentially constant depth over long intervals.

The converse of this process is equally true. If the pressure on the crust be released or decreased appreciably over a large, upwarped area, there will be a tendency for the substratum to flow toward that region of negative pressure. A place of this type is spoken of as a geanticline in contradistinction to a geosyncline. The two structures are commonly found in juxtaposition and closely related. As Appalachia was worn down and its eroded surficial materials were removed to the westward sea, it was lightened, and rose after the manner of a geanticline, as downward pressure in that region decreased.

During the Paleozoic era, a geosyncline occupied that part of the inland sea of North America that bordered Appalachia. Sedimentation in this tended, through weighting the crust, to force the fluid material of the asthenosphere to flow away from under it. Simultaneously, lessened pressure, due to erosion of Appalachia, produced a tendency for subcrustal matter to move in under the old land mass. Thus was brought about a species of ''hydrostatic balancing''. This process of attaining such a balance is called isostatic adjustment. When the sinking and rising elements balance each other, the condition is called isostasy.

The process, isostatic adjustment, appears not to have gone on regularly; it did not proceed at a uniform rate. At times Appalachia rose more rapidly, again it remained essentially static. When it stood high, streams were rejuvinated and much sediment reached the sea When it was quiet, streams wore it low and meandered with decreased loads down to tide-water. The geosyncline, too, seems to have behaved in an irregular manner and to have subsided ''by fits and starts''. Now the water grew exceptionally deep. Again, the sediments built up the bottom so fast that the sea was filled, and terrestrial conditions obtained. At still other times, erosion superseded deposition and ''breaks'' or lost intervals interrupted the sedimentary sequence.

Today, no active geosyncline exists within eastern North America. Appalachia is known as a mere remnant of crystalline rocks in our piedmont, and below the coastal plain. ''The clock ran down''. Why, no man has satisfactorily told. The sea finally filled, Appalachia was degraded. The interior of North America became *terra firma*. The Atlantic Ocean covered much of the old land. Nevertheless, for some hundreds of millions of years isostatic adjustment functioned. In our studies of the Devonian we are concerned with a part of these years.

Apparently, the geosyncline was subject to age long paroxysms at more or less regular intervals. Lesser paroxysms are called disturbances and may separate the geologic periods. The greater intervals of unrest are revolutions between eras. For eons the sea and land behaved in a ''normal'' manner with isostatic adjustment functioning quite steadily. Then irregularities interrupted the steady process, mountains rose up in the east, the sea withdrew temporarily from the geosyncline. Quiet being again restored, the waters returned, and another cycle of sedimentation in the geosyncline and interval of uplift and erosion of Appalachia began. Toward the end of the Paleozoic era came a paroxysm more violent than all its earlier ones. As yet unexplained forces appear to have driven Appalachia slowly but irresistably west- or northwestward against the geosyncline, crumpling, bending and breaking its beds and throwing them into the spectacular folds we witness today in the Appalachian Mountains. What caused this, the Appalachian Revolution, we know not; what it caused we can observe. It ended the history of the Appalachian geosyncline and the process of depositing its miles-thick sequence of bedded rocks.

Thus dwelt Devonian life. If we could have drawn a net through Devonian oceans, or dredged the bottom of the sea in the Appalachian geosyncline, or wandered along the coast of Appalachia, or tramped through Catskill Delta Land, strange forms of plant and animal life would have confronted us. The sea was abundantly peopled with "shell fish"; but, instead of our familiar clams, oysters, and scallops, there were myriads of brachiopods which in some ways resemble clams, but are really quite different. (See Bibliography for references on paleontology). True, clams and snails also lived on that old sea bottom or burrowed in its muds, but even these were not strikingly like those we know today. Coral reefs there were, but instead of harboring the beautiful, branched staghorn coral familiar to students of the modern ocean, there grew then curious stony cups like misshaped goat horns, rising among others whose rounded bosses remotely resemble our brain corals. Bryozoa or "moss animals" twined their more delicate branches among the true corals. Crawling on the bottom or nimbly swimming were shrimp-like crustaceans, and those ancient relations of our crabs and lobsters, the trilobites, in company with great sea scorpions, scuttled on the sandy bottoms. The cuttle fish tribe had its counterpart in heavy-shelled ancestors among whom some resembled our chambered nautilus. Seaweeds flourished and must have served as food for at least part of the animal swarms. Here and there a fish or school of fishes might have been seen to paddle by (84, 178, 151, etc.). Strangely slow and stiff were most of these, not the swift, agile kinds we know. Save for an occasional shark-like form all seem to have enjoyed the then popular fashion of wearing armor plate.

Forests clothed much of the land (3, etc.). Trees with leaves like great fern fronds rose forty, sixty feet above the plain. Among them were stiff, reed-like plants, but no flowering plant is known to have lived during the Devonian. The rivers had their fresh-water flora, and in the currents swam more armored fishes, perhaps in vast numbers ascending from the sea at spawning time to lay their eggs in the manner of the modern salmon. The muddier stream bottoms were the homes of bivalves not unlike our fresh-water "mussels". But in the forest one probably would search long for animal life. Doubtless there were "worms" in the soil. Perchance air-breating crustaceans hid in rotting logs in company with "thousand-leggers". Scorpions existed, since they are recorded from the older, Silurian rocks. No insects are known. Yet one is tempted to believe they or their ancestors knew the late Devonian forests.

What of land-living, air-breathing, backboned animals? They or their foot-prints are known in the next younger rocks, the Mississippian system, in Pennsylvania. The much maligned *Thynopus* track has been described as that of a Devonian amphibian from Pennsylvania. I, myself, have had the hardihood to assign a vertebrate origin to certain curiously, anamolous tracks and trails occurring in shale of Chemung age in Susquehanna County (241). But as yet no unchallenged evidence of the existence of terrestrial vertebrates has been demonstrated. No bones are known, only tracks of equivocal interpretation. Caster (36) recently published evidence that these tracks may be attributed to arthropods, but neither he nor I has seen the maker of the impressions.

In contrast with the antique biology of the Devonian, is the physical environment. The processes of inanimate nature were then as now. Water flowed. Streams came romping out of mountains or meandered through forested piedmont or swampy coastal plain to build their coastal deltas. The waves beat and the tides and currents washed the coast. Rain fell. The drops left little round pits in the mud. Occasionally a slab of shale bears raindrop pits or craters whose rims are all higher in one direction than any other. We infer from this that wind drove the drops at an angle onto the mud. When the shower was gone and the sun shone on the Devonian mud flats, the muck dried and cracked in the familiar polygonal blocks. Lush forests imply at least a temperate clime, but even in such, ice may form. If my determinations and deductions be true, ice did exist in Pennsylvania, perhaps only locally, in latter Devonian years. Whether there were winters and summers is uncertain. Some evenly-banded fresh-water shales of our Devonian suggest seasonal changes, but annual rings are unrecognized in our Devonian plants.

So in the Devonian we may picture a shallow inland sea bordering an eastward-lying land. From that land, rivers flowed west to salt water. The sun shone, rain fell, ice formed, wind blew, the tide rose and fell and currents carried the sea water hither and yon. Strange, abundant floras and multifarious faunas flourished. Among these forms of living things, some few were like our common types today. *Vice versa,* some of our rare moderns are remnants of these forms of long ago. The economy of life in the sea was even then much as it is today. The green-clothed lands, as yet all but unoccupied by animal forms, had still to achieve an approximation of the conditions of the Age of Man.

Devonian paleogeography. In the foregoing paragraphs, I have stated that the interior of the ancestral continent of North America was covered, during the Paleozoic era, to a varying extent and at different times by inland or epeiric seas. Like those of other Paleozoic periods, the seas of the Devonian period spread over large areas and covered different regions at successive times. The epeiric seas of the Silurian dwindled at the end of that period and may have left the continent high and dry. However, the doubt of a generally recognized physical break between Silurian and Devonian sediments in Pennsylvania seems to imply that here, at least, water continuously occupied the Appalachian geosyncline, if in only a small region, from the older to the younger period. In the early Devonian, a long, narrow sea reached from the Maritime Provinces south and southwestward to the Gulf of Mexico. It represented the then narrow Appalachian geosyncline along the western border of Appalachia. With the opening of Middle Devonian time, this sea continued, but was cut in twain shortly in the lattitude of New York State so that its fauna shows certain changes and peculiarities. In later Devonian times the geosyncline became confluent with a wide sea that reached from Alaska and the Arctic south, east and all through the present Cordilleran region and invading much of the Central States, came east into Pennsylvania. As the Devonian period waned, this sea shrank. Simultaneously and continuing an earlier condition, continental sediments filled in the now narrow northern end of the geosyncline in New York, New Jersey, Pennsylvania, and Maryland. Probably the sea withdrew entirely from Pennsylvania at the close of the Devonian period.

Marine transgressions. Such an advance of the sea as just described, from a small beginning, to a maximum flood, to a final curtailment, is supposed to mark a "typical geologic period". The advances and retreats are referred to as positive and negative transgressions. The Devonian was a fairly typical period, and Pennsylvania's Devonian sequence well illustrates the trend of sedimentary events. However, owing to proximity to the shore, the supposed natural sequence of lithologic types is obscured, partly through the dominance of relatively coarse, marine clastics and partly by continental sediments.

In such a period as the Devonian the march of events is said to be cyclic. A sedimentary cycle records, first an advance of the sea, the positive transgressions or *on-lap;* second a maximum areal submergence when an interval of quiescence, spoken of as *stillstand,* holds the stage; and third, the negative transgression, an interval of recession of the seas called an *off-lap.* In such a sequence, on-lap, stillstand, off-lap, there is an orderly succession of sedimentation. As a sea advances, sands accumulate near shore, muds farther out (usually in deeper water), and limestones at a still greater distance off-shore where free precipitation of calcium carbonate may take place unmasked by clastic, terrigenous sediments. As the sea advances farther upon the land, the region that was receiving sand (the strand and neritic zones) finds itself farther to sea where mud (pelitic zone) is now forming. Similarly, the erstwhile pelitic zone may be now a lime-receiving area. Thus, *whether the on-lap series of sedimentary types be counted from the shore outward, or from the lowest unit of the advancing cycle upward, it should, during the positive transgression of the sea upon the land, be always sandstone, shale, limestone.* It may be readily seen from this how sandstone, shale and limestone form contemporaneously and grade literally into each other. At the time of maximum flooding when the sea has ceased to advance, but has not commenced to retreat, there comes a quiescent pause. Sand may accumulate along the margin, but beyond, sedimentation is restricted. Dark mud and limy ooze may form in limited amounts and to no great thickness. Eventually, the "tide" turns. Gradually, the sea withdraws. Off-lap replaces stillstand which had followed on-lap. Again, there is the sandstone, shale, limestone sequence from the shore outward, but now, *in a negative transgression mud is laid down on top of the limy ooze, and sand creeps out and caps the muds. The sequence, sandstone, shale, limestone, is the same from shore out-*

ward and from above downward. We thus may find sandstone, shale and limestone of contemporary age intergrading laterally. In off-lap there may be another distinctive element. As the seas withdraw or the geosyncline fills in, continental sediments gradually displace the latest marine sandstones, writing the final chapter of the cycle.

A cross section through the sediments of a complete cycle is idealized in Figure 94. The lowest and highest surfaces that converge landward, disregarding the continental units, will be sandstones. The lower sand represents progressive advance of the neritic zone and the strand, the upper represents progressive recession of the same. The lithology may be similar throughout, but at no two points will these sandstones be of precisely the same age in the direction of transgression. Likewise, the muds and limestones represent less extensive, though perhaps thicker layers within and parallel to the extreme, sandy members. Horizontal lines drawn across the diagram are traces of planes of contemporaniety, if we assume relatively uniform sedimentation rates. So, while the lithologically same sediment crosses these planes obliquely, the sandstone, shale and limestone along any one plane were formed contemporaneously. The successive fossil faunas occurring in each sandstone are either ancestral to or descended from those at adjacent higher or lower points. The faunas in the sandstone, shale and limestone along a particular plane of contemporaniety only, lived at the same time. The planes above the zone of greatest areal extent or stillstand may be farther projected into the continental sediments denoting what portions of these same formed simultaneously to particular marine sandstones, shales or limestones. Actually, these planes would merge into upcurving surfaces in the continental beds in most instances, owing to excessive thickening of the non-marine compared with its marine correlates. The sandstone, shale, limestone or continental beds are, of course, locally mapped as formations. Actually, they are often contemporaneous facies, strand, neritic, pelitic, continental and so forth, representing different environments of the region at the given time. We shall see that many of our formations are, therefore, facies expres-

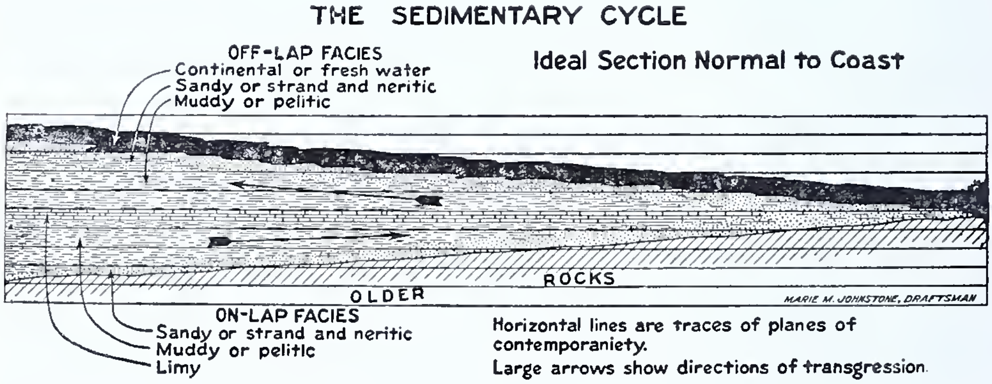

THE SEDIMENTARY CYCLE
Ideal Section Normal to Coast
OFF-LAP FACIES
Continental or fresh water
Sandy or strand and neritic
Muddy or pelitic
ROCKS
OLDER
MARIE M. JOHNSTONE, DRAFTSMAN
ON-LAP FACIES
Sandy or strand and neritic
Muddy or pelitic
Limy
Horizontal lines are traces of planes of contemporaniety.
Large arrows show directions of transgression.

Figure 94. **The sedimentary cycle illustrated, an idealized cross-section normal to directon of transgression.**

sions, shifting regions of a continually advancing or retreating sea. *Correlation should, therefore, follow the planes of contemporaniety; organic evolution must follow the respective lithologic facies.*

The cycle as above outlined is, of course, idealized. In actual practice one rarely, if ever, encounters a complete sequence. Either, it was never fully developed, or has suffered subsequent obliteration in part through succeeding intervals of erosion or deformation. There are local irregularities. On-lap or off-lap are not necessarily steadily progressive. Fluctuations and hesitations, reversals and resumptions of the trend take place, so that transverse profiles of contemporaneously-forming bands of sandstone and shale are usually ragged, cut up by many small zigzags. The result is the recurrence of certain lithologic types with characteristic faunas in a given vertical section. These are particularly patent in regions that lie at or near not only the border between facies, as where sandstone and shale were formed, but where marine and continental phases tend to oscillate temporarily for mastery before the final change sweeps on over the section in question and its sediments become dominated by a particular type in which is buried its distinctive fossil biota. We may now turn our attention to the Devonian cycle in Pennsylvania and try to understand it as an on-lap, stillstand and off-lap.

The Devonian cycle in Pennsylvania. Much of the Devonian of Pennsylvania appears to have been laid down in a part of the Appalachian geosyncline which included a large gulf, aptly termed by Caster, the Penn-York embayment. Referring to the map (Figure 46), it is observed that the shore at the time of maximum flooding probably entered the State near its south-central border and trended northeast to and about the Cape Cumberland west of the present Susquehanna Valley. Thence, the coast swung in a wide arc southeast, east (Lebanon Bay), northeast, and finally north across New Jersey, into or not far east of the Hudson Valley, only to turn northwest and west again across central New York and off into Ontario. Into this embayment overflowed the waters of the epeiric sea. Here formed our Devonian strata. Here, finally, the Catskill continental facies obliterated all sign of the marine environment. That the Penn-York embayment was open to the midwestern sea is proved by their related faunas; that is was large and partook of the physical properties of that sea, cannot be denied. This is borne out, if we recall the southward deflection of our late Devonian delta lobes, by a postulated clockwise rotation of the waters of the sea.

Our first information regarding the sediments of the embayment comes from the Helderbergian. The limestones and limy shales of the Helderberg group do not fit into the orthodox scheme of cyclic deposition. Rather, they appear to be relics from late Silurian conditions when a restricted incursion of the sea (Tonoloway and Keyser calcareous sedimentation) followed the Silurian continental facies, the Bloomsburg red shale, and closed Silurian sedimentation. The Helderberg sea occupied much of the embayment, lapping across Pennsylvania into northern New Jersey and on into the Hudson Valley Here and there sandy and even pebbly beds in our eastern sections justify the belief that the coast was near at hand. Either that shore was very low, was itself composed largely of limestone (an improbability) or the climate was so arid that little or no clastic material was washed to sea. Judging from interpretations of late Silurian environment, the last explanation is the most probable. At the end of Helderbergian time probable commencement of the Devonian cycle came with the invasion of the Oriskany sea.

Much of the Oriskany sandstone with its pebble beds and large, thick-shelled invertebrates is doubtless a neritic zone or beach deposit formed near or on Appalachia's coast. But the sands spread far outward over the shallow bottom. Deep wells in north-central Pennsylvania encounter Oriskany sandstone at points probably midway between the north and south shores of the embayment. Such a condition may have an approximate counterpart in the shallow, but sandy-floored North Sea today where strong currents in a constricted area sweep the finer sediments away, leaving a bottom deposit of relatively pure quartz sand.

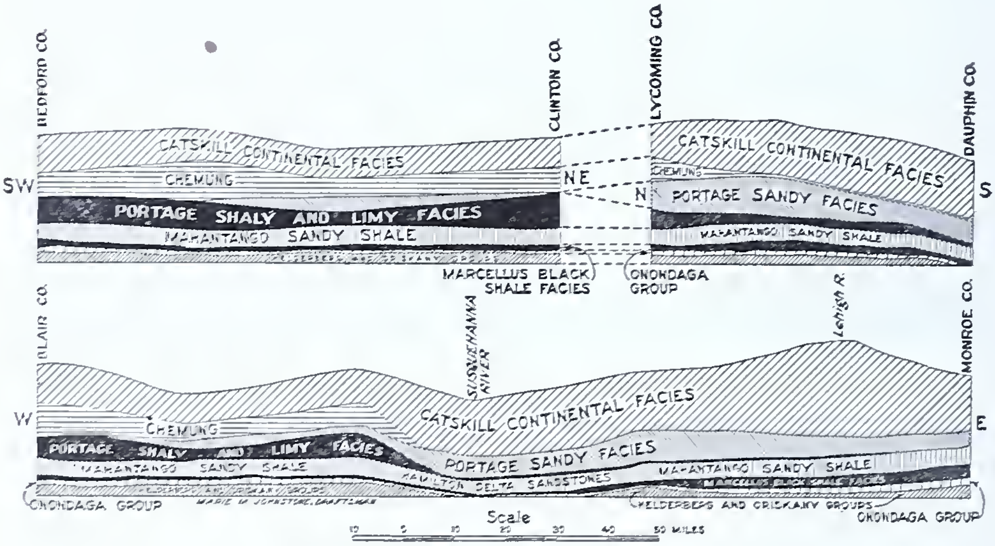


Figure 95. **Generalized sections of the Devonian of Pennsylvania drawn to show particularly the facies shifts, vertical scale greatly exaggerated. See key map, Figure 93, for locations of sections.**

The Oriskany is abruptly followed (disconformably in Pennsylvania at least) by the Esopus sandy shale or muddy sandstone. The "break" may be due entirely to a change in type of sediment supplied or a modification in the currents agitating the Penn-York embayment. It is difficult to vision a withdrawal and return of the sea. Nevertheless, the absence in Pennsylvania of any trace of the Schoharie of New York is irrefutable evidence of an interval of non-deposition if not erosion. The development of chert and local concentrations of iron in the upper part of the Oriskany bespeak a period of exposure which I am inclined to look upon as of appreciable duration. Certainly, the abrupt change of faunas indicates some new sea connection that opened at the end of Oriskany time. Mud and muddy sand succeeded the cleaner Oriskany sands to the east. Farther west, in central and south-central Pennsylvania, the contemporaneous Needmore limy shales formed. Gradually in the more central parts of the embayment, and east even to the Delaware Valley, the waters cleared and limestones of the Onondaga group were precipitated, but the calcareous facies never reached as far east as north-central New Jersey, where only mud and sand of Onondagan age are recognized. This region may be thought of as roughly approximating the position of the head of the embayment at this time. Along the southern or southwestern borders of the bay, mud continued to dominate, with only occasional limy beds interspersed, and local ("marginal") unconformities imply a few spots of nondeposition. Locally the lime carbonate was displaced by black mud, precursor of the succeeding Middle Devonian sediments. The Onondaga limestones probably mark the maximum advance of the cycle or stillstand. They represent the widest incursion of the lime-forming sea of the advancing cycle of the Devonian. With the Marcellus, approximate stillstand was continued. In it, indeed, we have clearly illustrated the typical sequence from shore outward. In north-central New Jersey the Marcellus is represented by a sandstone with characteristic Mahantango ("Hamilton") fossils. Across most of Pennsylvania it is black shale with Marcellus organisms. Nevertheless, it is distinctly sandier in its eastern parts, and a local delta in the Susquehanna Valley attests the nearness of the coast in that area. However, where the Marcellus is passing under the later beds of the Allegheny Plateau in Lycoming, Centre, and Huntingdon counties, in a region far removed from the land, limestones displace the shale. The east-west sequence, sandstone, shale, limestone, is thus nearly complete. One is tempted to prophesy that deep drilling in west-central Pennsylvania would show a Marcellus limestone completely displacing the black shale facies. The sea continued at its maximum into early Mahantango time, but there were even then signs of change. Already, continental beds, the first of the Catskill facies, appeared in the Hudson Valley, in north-central New Jersey, and Fulton County, Pennsylvania. Still, in Lycoming and adjacent counties, black shale of the Marcellus type with a Marcellus recurrent fauna occurs among the Mahantango beds. The wide distribution of the Onondaga limestone much beyond the limits of the Tully, the succeeding Marcellus black shale (the most persistent unit in the Devonian of Pennsylvania), the general lack of coarse clastic sediments in both Onondaga and Marcellus times, and the initial signs of continental Devonian sediments about the close of Marcellus time all point to this as the turning point of the Devonian cycle. Substantiating this is the presence in the Onondaga of a new fauna distinct from the Oriskany, a fauna whose descendents continued with intermittent introductions of new elements and losses of old through Hamilton, Portage and Chemung formations. Lesser incursions followed. None were comparable in extent to that of the Onondaga and Marcellus. I shall mention particularly only that of the Tully and Burket. With earliest Mahantango sedimentation the latter part of the Devonian cycle was in full swing. It terminated only in the final overwhelming of all in the Catskill fresh-water facies.

The termination of the Hamilton is marked by a temporary interruption of off-lap. Characteristic Hamilton sedimentation ceased over wide areas in the central counties. Limestone (the Tully) and the succeeding black mud (the Burket) superceded it. Probably there was no diastrophism save in the south-central areas where the highest Hamilton beds are thought to be lacking. Locally there was an interval of quiet following the initial off-lap stage. The black Burket mud crept east beyond the Lehigh into western Monroe County, and there passed into lower Trimmers Rock sandstone. Farther to the west the Tully limestone covered the quiet sea bottom. But off-lap continued in the extreme east even as there was an interruption of the process in the central region. The sandy, eastern Hamilton passes up through an unbroken sequence into the lithologically similar Trimmers Rock sandstone. There is nearly as little faunal change as there is lithologic. Almost before the Tully, Burket and Harrell had formed, the muds of the interior of the embayment began to change from black or gray to greenish. Rapidly, the complimentary arenaceous phase, the Trimmers Rock sandstone, overspread and displaced the pelitic phase, the Brallier green to gray shale. Stray sandstone fingers reached west and groped in the muds. They represent minor fluctuations along the line of phase change between sand and mud. Before the close of Portage time, the sands had practically displaced the muds all the way to the Allegheny Front. The displacement was completed in Chemung time.

Our marine Chemung is, to all intents and purposes, a continuation of the arenaceous marine facies of the Portage sedimentation typified in the Trimmers Rock sandstone. It completed the overwhelming of the Middle Devonian muds to the west and was itself continued in the later marine units of the Chautauquan whose final expression is recorded in the Conewango of our northwest counties.

Catskill continental beds commenced first to form in north-central New Jersey and the Hudson Valley in early Mahantango if not late Marcellus time. Their advance, save perhaps for partial retardation in Tully-Burket time, was steadily west and northwest. They appear in middle Portage time in eastern Pennsylvania. They transcend the Portage in the Susquehanna Valley where the easternmost marine Chemung fossils are found in Luzerne, Perry, Dauphin and Susquehanna counties. Yet even here, in the southeastern corner of Perry County, Catskill red beds displace the latest Portage so that no Parkhead occurs and comparatively little of the Trimmers Rock appears to be present (Structure is obscure. Faulting may have cut some of the Portage here). The red beds advanced not only from the east, but from the southeast and perhaps even the south. By fairly late Chemung time the terrestrial condition reached the Allegheny Front. There the further advance is hidden under the Mississippian and Pennsylvanian formations of the Allegheny Plateau. But, along our northern tier of counties, the closing drama of continental off-lap is recorded with the Catskill steadily devouring one marine unit after another until it finally encroached upon the highest in our most northwestern sections.

Such was the Devonian cycle in Pennsylvania. Such was its advance and retreat. It had its fluctuations, its local exceptions to the ideal sequence, but on the whole, we observe a fairly complete sequence of on-lap, stillstand, and off-lap terminating in continental conditions.

Devonian orogeny. Can we reasonably deduce anything rational as to the *causes* of the *effects* observed in the Devonian cycle? Is it possible to determine even approximately the source of supply of at least some of the sediments? Can we account for the changes from fine to coarse, from marine to continental? Is it feasible to ascertain the direction from which the sediments may have come? What events were transpiring in Appalachia which may have had direct or indirect bearing upon these happenings in the old Penn-York embayment?

Some of these questions are answerable with considerable certainty; of others, a hint of the answer may be suggested; for the rest, there is no ready explanation. It was observed that the rate of subsidence of the geosyncline could hardly have been constant: Such a conception is based upon the observations of fluctuations in the cycle and that the widespread sandstones, dark shales and limestones were probably deposited at different depths in some cases. If, as is sometimes postulated, such black shales as the Marcellus and Burket formed in relatively deep water, as off the 100-fathom line of the continental shelf, considerably deeper water may be postulated than for the ripple-marked, sandy shales of the Mahantango and later Portage. Occasional conglomerates have been recorded in the Devonian of Pennsylvania. Most of these are found in the continental facies, but Oriskany, Mahantango and Chemung carry them. In the first they may represent strand or neritic zones, in the second they are thought to be part of a delta. The few thin conglomerate beds or lenses recorded in the latest Chautauquan in northwestern Pennsylvania are accountable as near shore, tidal or estuarine sediments; or, like the Oriskany, they may be more or less littoral, since they occur in marine strata which pass over into continental beds in short lateral distances. There is no widespread, conglomeratic marine or even partially marine Devonian facies alanogous to the Shawangunk and Tuscarora of the Silurian. Rather, the fresh water conglomerates have the character of the later Pocono and Pottsville which are, from all available evidence, non-marine in eastern Pennsylvania. The thickest and most persistently conglomeratic Devonian beds are recognized in the non-red units of the Catskill, particularly the Honesdale. From this I exclude such unusual deposits as the Dyberry glomerate and similar local, nearly contemporaneous strata. There are also fairly widespread conglomerates among the red beds themselves, typified by the Pimple Hill in the northeast and various conglomeratic zones (I. C. White's Lackawaxen for example) in the south-central areas. These are difficult to explain. They may be in part channel deposits or represent short intervals when, through diminution of supply of fine sediments, local reworking, or fluctuations of climate, only coarse material was left. I have mentioned the similarity of the Honesdale of late Devonian age to the early Mississippian Pocono and how for years the two were confused, largely because of strikingly similar lithology and distribution. It is altogether probable that their origin was similar both as to source of materials and method of deposition. In this same category, though composed of finer clastics, is the Elk Mountain sandstone and the Paupack member. Briefly, if one examines the continental Devonian and Mississippian of eastern and northeastern sections, he cannot fail to be impressed by the sequence of prominent red and non-red members. The thin Analomink red shale marks the earliest appearance of fairly persistent red in the northeast. The proportion of red beds increased and dominates in such thick units as the Damascus, Mount Pleasant and Cherry Ridge, but from the Delaware River flags and the Paupack on through the Honesdale and Elk Mountain, gray or greenish-gray sandstone and conglomerates become important alternates with the units composed chiefly of red strata. Looked on as a whole, the culmination of these non-red members was reached during post-Devonian, Pocono deposition, though red sedimentation returned for a final flourish in the Mauch Chunk, in turn to be blotted out by the Pottsville conglomerate. Such changes cannot be easily attributed to variations in the depth of the Appalachian geosyncline, for they took place after it had filled. Purely from the nature of the rocks, it is extremely difficult to establish whether they formed as coastal plain sediments in a subsiding area which persistently remained above sea level, or were piled up as thick piedmont deposits adjacent to the backbone of Appalachia. Barrell (11, 12, 13) seems to have favored the latter conception, and my own observations lead me to support that view.

When a mountain range is rising, erosion is accentuated. The higher the mountain rises, the greater the weathering and erosive powers that attack it. A constant struggle is waged between subcrustal forces of elevation and meteoric and surficial forces of degradation. Eventually, with discontinuance or slackening of uplift, the process of reducing the elevation wins; the highlands are humbled. But, while both powers are active, while erosion is strong, there will be produced about the foot of the mountains, that is, in piedmont regions, deposits of gravel and coarse sands often of great thickness. Our modern mountain ranges, the Alps, the Rockies, bear out this statement. Were the Alps obliterated and the conglomerate and coarse fresh-water sandstones of the *Flysch* and *molasse* along their northern bases preserved, we should deduce that once a mountain system rose to the south. Such are precisely my deductions as to the origin of our non-red members or facies of the Catskill and of the Pocono. To my mind, they represent material swept from a rising mountain mass lying east and southeast in Appalachia. The elevation of the mountains was sporadic or, better, spasmodic. With each new uplift, sheets of sand and beds of pebbles spread west and northwest over the piedmont. They are thickest, coarsest, heaviest bedded toward the southeast (*cf.* Honesdale and Pocono variations). The intermittent uplifts increased in violence to the last grand movement at the close of the Devonian period. So profound were its effects that the sea even in northwestern Pennsylvania withdrew from the last remnant of the Appalachian geosyncline within the State. The great onslaught of pebbles and sand that followed is preserved in the Pocono. This final convulsion of mountain building is conveniently responsible for sharply delimiting the Devonian orogenically and stratigraphically from the Mississippian. The results of this intervai of orogeny is our expression of the Acadian disturbance which, in severer form, punctuated the closing years of the Devonian in the Maritime Provinces and northeastern United States.

Origin of the red Catskill. What of the red units of the Catskill facies, if the non-red parts are the direct expression of Acadian orogeny? Here is reared the head of the unlaid spectre of the origin of red beds, a controversial theme almost as old as the science of modern geology. It is not my intention to re-open that conflict, nor am I anxious to add any new theory. Rather, I am inclined to explain these red beds through suggestions already extant. I have not fully accepted all points of any one theory. Rather, the best parts of at least two of the more recent explanations seem applicable. I refer particularly to those of Joseph Barrell (13) and Percy E. Raymond (166). Both are masterly exposition by two of the keenest observers of American Paleozoic stratigraphy.

Barrell postulated that the red beds, speaking particularly of the Old Red of the British Isles, but applying also to the Catskill and Mauch Chunk, originated under a particular and exceptional phase of sedimentation ruled by semi-arid climatic conditions. He suggested simply a succession of alternate wet and dry seasons. During the wet season, streams from the mountains distributed vast sheets of sediments. In the dry season, complete oxidation of small amounts of ferrous iron present in the sediments produced the red color. To this, Raymond objects. The constructive criticism offered is chiefly that life was too abundant to admit prolonged seasons of drought and that dry seasons are an inadequate cause to redden the clastic sediments. With the first of these objections I concur, for certainly there was a wealth of plant life in the Catskill terrane, sufficient to have produced thin coal beds locally. The streams supported an abundant piscine fauna. As to the inability of the sediments to be turned red during a season of aridity, Raymond's objection appears fully supported from my own, admittedly limited, observations or understanding of sediments forming today under conditions approximating those suggested by Barrell. I am, nevertheless, in entire accord with Barrell as to the piedmont or coastal plain or even deltaic origin of the sediments. The method of origin he supported, not the method of coloring, meets with my own ideas. Raymond suggests that the sediments had already assumed a red hue prior to transportation and deposition. This theory I heartily second. One has only to journey through our limestone valleys or visit those of the more southern Appalachians to be impressed with the reddish soil colors. Red soil is seen in travelling from Richmond westward to the mountains of Virginia. Here, in a region underlain by crystalline rocks, not limestone, there is observed reddish residual soil oxidation in deeply weathered areas. A species of laterizations is going on under our very eyes. Yet vegetation is abundant and the winters are comparatively cold. How much more intense the production of laterite is in the moist tropics is a geologic axiom.

During the intervals of quiet that separated times of rapid uplift of the highlands of Appalachia throughout the progress of the Acadian disturbance, it is conceivable that, after the first period of rapid erosion, the heights were reduced and weathering in situ overbalanced erosion. Under such circumstances, laterization conceivably could progress a pace. Deeply oxidized soils should accumulate. Red or reddish soils could form, even in the presence of vegetation, if the climate were not too cool. That the late Devonian may have been temperate is attested by the occurrence of ice. But the evidence drawn from the presence of corals in the sea throughout the period implies anything but a frigid climate. The abundant land flora is supporting evidence for such a contention. Now, let the rivers, their transporting powers reduced through lowered gradients, carry the red soil seaward and spread it wide on lowland, piedmont and coastal plain. With rejuvenation, the streams for some time must be occupied in reworking the lateritic rock mantle. The result,—red beds whose color is chiefly, as Raymond has postulated, of primary origin, unlike Barrell's theory of secondary coloration.

These postulates find further credence when one notes the contact between red and non-red units. The older literature teems with accounts of "transitional" beds between these members. Such, in a sense, these are. However, from the foregoing orogenic theory, if residual soils accumlate during intervals of quietude, when erosion is accentuated, the first loads of the rejuvenated streams must consist largely of transported regolith. As this is cleared away, more and more unaltered material is incorporated in the loads of the rivers until finally, in a later stage, only relatively fresh rock fragments are being transported and deposited. But, during the transition between dominantly red and dominantly grayish sediments, an alternation between the two must obtain. *Such is the nature of the transitional beds.* Therefore, based upon the orogenic explanation of alternation in Catskill sediment types, the first red bed of a "transition" may be considered the base of the succeeding, dominantly red unit. Conversely, the first gray stratum is the initial indicator that rejuvenated streams caused by renewed mountain building and uplift are cutting deep into upraised rock, stripping it of its red regolith.

So, through middle and late Devonian time, the mountains of Appalachia alternately rose and were degraded. When they stood high, laterite or reddish soils had no place to form. Rapid erosion bore the coarse detritus away, and youthful rivers carried it down to form the non-red, sometimes pebbly units of the Catskill, typified by the Honesdale. When the mountains were reduced, red soils accumulated and mature or "old age" streams ran red in time of flood.

This is an orogenic explanation of the marked alternation of color among our Catskill members. In closing let me say once more that the relative thicknesses and areal distributions and variations in texture of these same units point to the southeast as the major region from which these clastics came. The old sea was extinct; and, where the Penn-York embayment had spread its salt flood, a thick wedge of fresh-water-formed beds was next built up, its feather edge toward the northwest, its base far to the southeast, partly beyond the limits of our Commonwealth, abutting against highlands which rose where Washington, Baltimore, Philadelphia and New York sprawl today, spreading metropolitan vastnesses unconscious of the alpine roots beneath their cellars.

EPILOGUE

The old conflict between uniformitarianism and catastrophism is not done, forgotten, dead and buried even at this day and state of geologic knowledge. Many a twentieth century geologist calls himself a uniformitarian, but a distressingly numerous percentage of us are still catastrophists at heart. Old misapprehensions wrap cephalopodian tentacles about modern concepts. Geologic revolutions are said to be separate eras; disturbances are called the dividing lines between periods. As a means of punctuating geologic time, the revolution is usually valid, the disturbance less often so. The magnitude of the disturbance, both as to duration and extent of region affected, varies. Was the Cascadian revolution more cataclysmic than either the Caledonian or Acadian disturbances? Many periods, seemingly established upon disturbance-marked limits, have, except locally, no such precise boundaries. The revolution may be far flung, but is it ever truly world wide? How much more local must be the disturbance? The sedimentary cycle should be and to many is the basis for defining the system and in turn limiting the period. Minimum floodings mark the interperiodic or intersystemic nodes of an era. Greatest floodings represent the maxima of systemic, areal development. Yet even here our concept tends to break down, for the floodings and recessions of the seas are not necessarily chronologically amenable to universal correlations or even over a single continent. Nevertheless, it is the sequence of sedimentary cycles that makes the era truly periodic.

What is the areal magnitude of the rocks formed during a cycle? If they were produced by a world-wide change in sea level or a world-wide uplift or depression, simultaneously, of all the land masses, the definition of our periods and systems would prove a relatively simple matter; and the correlations between remote regions would bring joy to the hearts of the stratigraphers and geologic historians. But, the individual cycles seem to be due to isolated, epeiric movements with or without orogenic accompaniment. Our very paleogeographic and paleophysiographic maps and charts witness not only this but also the still more restrictive facts that continental, diastrophic movements and mountain building are, often as not, confined to only one part, and perhaps a relatively small part, of a particular major landmass. Thus, the up-warpings and down-warpings of the continental crust of our own North America, movements which were responsible for the development of its geosynclines, its epeiric and its epicontinental seas, are often local and appear first in one quarter or another and thence spread to adjacent domains.

A sedimentary cycle, be it emphasized, is expressed in a sequence of sediments deposited during a more or less complete continental submergence. Fragmentary or incomplete cycles are recognized. The cycle may or may not be modified by contemporaneous mountain building, and the strata of the cycle may or may not be the close chronological equals of other strata spoken of as belonging to the same system but laid down in separate or only remotely connected geosynclines or epeiric seas.

Consider the Devonian of eastern United States, particularly of Pennsylvania. No orogenic activity punctuated the close of the Silurian. Where is the intersystemic hiatus immediately before the Devonian? The relations, physical and biologic, between the two systems are essentially transitional. The so-nominated, early Devonian (Helderbergian) was marked by physical conditions almost identical to the latest Silurian. The Appalachian geosyncline was occupied by a widening invasion of a shallow, lime-depositing sea. The Devonian cycle was initiated in characteristic and distinctive aspect only in Oriskany sedimentation; the maximum flood followed in late Onondagan and early Marcellus time. Recession or negative transgression with continental off-lap began somewhere about Marcellus or early Skaneateles (earliest Mahantango) time. What stillstand there was seems recorded in the Onondaga limestone and probably in part too in the Marcellus black shale. The recession is broken by only one important interruption, the Tully-Burket-Harrell interval, which, subcyclic in character, is less all-embracive areally than the Onondaga-Marcellus interval. The Acadian orogeny was truly a disturbance whose effect was directly or indirectly appreciated in Pennsylvania.

Long usage has separated the Devonian system into three parts. The Lower is marked off from the Middle at the top of the Oriskany. The Middle and Upper are split at the Tully. Dissention from this scheme exists today, has persisted for years. The Devonian or Silurian assignment of at least the lower part of the ''Helderberg'' (Keyser) has been debated. The Middle or Upper Devonian affinities of the Tully fauna are questioned. If a truly cyclic interpretation be put upon the system it is more correctly bipartite than tripartite. There is merely a Lower and Upper Devonian representing on-lap and off-lap, since stillstand leaves relatively little record. Long usage is a rock which will withstand to a remarkable degree, the erosive and weathering power of dissenting opinions. Nevertheless, I protest against the trisection of the Devonian, at least in Pennsylvania and adjacent regions. I would separate the Lower from the Upper Devonian at the top of the Onondaga limestone. There is much in support of I. C. White's drawing the base of the Devonian at the bottom of the Oriskany. There, the on-lap of the cycle really began; there, a marked physical and biologic change shook off persistent Silurian traits of the Helderberg and assumed a Devonian aspect. As a compromise with the ''die-hards'' who will gasp in horror at my iconoclasm, I am willing to call the Helderberg (though not included in the true Devonian cycle), and the Oriskany, Lower Devonian,—Onondaga, Middle Devonian,—and the post-Onondaga part of the system, Upper Devonian. To those who insist on conformity with European sequences, this arrangement, of course, will never find favor. My suggestions are not made with the hope of their immediate recognition. I am not anxious to see accepted any rash assumptions based upon data drawn from an admittedly limited area. Such should not alter time-honored concepts without thorough criticism. In the body of this report I have used the orthodox and conventional Lower, Middle and Upper Devonian definitions. This classification I protest as illogical, but as yet it is not sufficiently decadent to be relegated to the limbo of Rogers's fantastic terminology.

Furthermore, I protest the present use of such terms as group, formation and member. There is a deplorable tendency to map time, not rocks. I object. *System,* I would retain in the sense of connoting the rocks of a designated period produced during a major cycle. *Group* is less offensive than formation or member. It may be retained, but I prefer to see it applied to the strata laid down during a particular, cyclic phase, as an *on-lap group* or *off-lap group.* Geographic names might even be tacked on in such a nomenclature. If formation be truly a "mappable unit", amen! But there is too much looseness in its application. Beds of totally different facies may be mapped as the same formation. Such is hardly a unit, however mappable. I should prefer to confine the meaning of formation to a *mappable facies.* Variations of that facies such as may be produced by a temporary interruption of transgression may be designated as members, and in so doing many actually are identical to plenty of members and formations recognized today under the present system of identification.

The geologic system is cyclic, and as a cycle of sedimentary rocks, its sequence must be unravelled, its component parts and distribution interpreted, both as to areal distribution and contemporaniety. It is composed of continuously formed facies, themselves ever changing in age and passing laterally into beds of another facies, formed simultaneously, the whole mutually complementary. Caster (33, 34) has described the facies development of the late Devonian and early Mississippian beds of northwestern Pennsylvania and southwestern New York. What he has described in detail is a concept long recognized in general for this and many other regions. His nomials, magnafacies and parvafacies, are convenient, but superfluous in the already term-glutted phrasiology of stratigraphy. Nevertheless, I have seen fit to allude to them more than once in this report. Whether we eventually shall speak of parts of the sedimentary cycle in Caster's terms remains to be seen. Whatever the final nomenclature turns out to be, I devoutly hope that a simple, really rational one based upon the true and correct application of the marine transgressive cycle will prevail. I look forward to the day when our stratigraphically trained geologists will map sedimentary facies as freely and truly as their co-workers, the specialists in igneous and metamorphic phenomena, delineate the multitudinous ramifications of the rocks in their chosen provinces.

CHAPTER XI

PALEONTOLOGY

INTRODUCTION

To date, no adequate attempt has been made to illustrate the Devonian faunas of Pennsylvania. Extant works cover geologically and geographically only limited portions. Caster (32) illustrated many of the later Devonian forms from our northwestern counties. Thanks to his work, it has been deemed unnecessary to include much of this material in this report. Swartz (209, 211) has illustrated a number of the Lower Devonian ostracoda. Kindle's Onondaga studies (127) figured a few of Pennsylvania's fossils. I myself have figured certain new or representative Tully fossils (255). Incidental articles from time to time have appeared which contain illustrations of Devonian fossils from Pennsylvania. Among their authors are Arnold, Beecher, Cleaves, Eastman, Ehlers, Eller, Hall, Newberry, Vokes and Willard. Their articles are found among the references in the appended bibliography. Despite all these articles, most of the Devonian fauna of Pennsylvania remains unillustrated. Consequently, it is fortunate that our Devonian fossils are predominantly those of species which have been figured from and are well known in neighboring States. Thus, in New York, the classic tomes of James Hall and John M. Clarke (112, 113, 114, 115, 116, 117, 118, 119, etc.) and other outstanding workers at Albany are our chief source of reference. These books themselves include illustrations of a few specimens actually collected in Pennsylvania. The Geological Surveys of Maryland (143), New Jersey (223), and Ohio (163) have also contributed bulletins that illustrate Devonian fossils common, too, in Pennsylvania.

The Devonian faunas of Pennsylvania, especially those of the Middle and Upper Devonian, appear to be both numerically and specifically poorer than those of the corresponding strata in New York. Conversely, they usually exceed in abundance those of Maryland and New Jersey. Surprisingly few new species are recognized in our Devonian. It is not the purpose of the present report to exhaust the possibilities of Devonian paleontology in Pennsylvania. Specific descriptions and synonymy are omitted. For this reason most new species are omitted, and very few fossils whose specific identity is undetermined are included. The scope and purpose of this bulletin hardly warrant such data. In other words, it is the intent in Chapter XI to publish a series of illustrations which will serve as a key to the Devonian faunas of Pennsylvania. It seems particularly desirable to have a work available in which the common Devonian forms of the State are illustrated and their presence in Pennsylvania thereby established. Eventually, a fuller treatment of the paleontology of the system may be undertaken.

No apology is offered for the material used as illustrations, however fragmentary. It must be recalled that our Middle and Upper

Devonian is dominantly clastic—it mostly lacks the limestones and the shale facies, of New York. Where a prominent shale facies does develop, such as the Brallier, it may be found nearly barren. Therefore, many of our specimens, originating in shallow water, buried in sandstone, are poorly preserved and fragmentary. Identification may have been based upon several poor or broken examples, of which one or two of the best have been photographed. As far as possible retouching has been avoided, but in certain cases, notably among the Middle and Upper Devonian pelecypods and gastropods, it has been necessary to make some slight alterations of the original photographs and to indicate the outline of an entire specimen where only a fragment is figured.

The Keyser and Helderberg faunas and Shriver ostracoda are illustrated entirely by Frank M. Swartz; I am chiefly responsible for the Oriskany and later figures. Exceptions are certain of the Onondaga fossils from the Lehigh Valley paint ores which were photographed by Lawrence Whitcomb. His original negatives were kindly loaned me for use in this bulletin. The Tully fossils are largely taken from illustrations from my recent Tully paper (255). These were prepared by G. Arthur Cooper and A. K. Miller, whose help is here acknowledged afresh.

The plates are arranged to conform to the distribution of materials in the foregoing chapters. Thus, Plates 1 through 7 illustrate Chapter II on Keyser and the Helderberg by Frank M. Swartz. Plates 8 through 14 are figures of the Oriskany of Chapter III by Arthur B. Cleaves. The remaining, Plates 15 through 32, are of Middle and Upper Devonian fossils (conventional usage) to accompany my chapters on those epochs.

DESCRIPTION OF PLATES

PLATE 1

KEYSER FOSSILS

(All Figures x 1, except as noted)

1. *Cladopora rectilineata* Simpson and other corals, x 1¼; coralline beds, 63 feet below top Keyser limestone, section opposite Beth Israel Temple, Altoona, Blair County.

2a-c. *Chonetes jerseyensis* Weller, external mold, dorsal valve, retaining part of shell, exterior of incomplete ventral valve and interior of a ventral valve. Respectively from: *Gypidula prognostica* subzone, 68 feet below top Keyser limestone, Penna. R. R. south of Mexico, Juniata County; 10 feet above base Keyser, east side Pine Creek near Jersey shore, Lycoming County; *G. prognostica* subzone, Keyser limestone, 1 mile north Selinsgrove Junction, Northumberland County.

3a-e. *Gypidula prognostica* Maynard. 3a, b, ventral valve, and slab showing abundance of species; *G. prognostica* subzone, 68 feet below top of Keyser limestone, Penna. R. R. south of Mexico, Juniata County. 3c-e, dorsal views of 2 large shells, side view also of first; plications rather weak; *G. prognostica* subzone of Keyser limestone, north bank Juniata River, opposite Mt. Union, Mifflin County.

4. *Camarotoechia gigantea* Maynard. Incomplete ventral valve; middle Keyser limestone, north side Juniata River, opposite Mt. Union, Mifflin County.

5a-c. *Stenochisma deckerensis* (Weller). 5a, dorsal view; 2 feet above base Decker limestone, old William Nearpass quarries, N. J.; 5b, c, somewhat smaller ventral and dorsal valves, respectively; Decker sandstone member Keyser, Croasdale Manor east of Stroudsburg, Monroe County, and lower part Keyser limestone, about 6 miles east of Williamsport, Lycoming County.

6a, b. *Rensselaeria mutabilis* (Hall). Dorsal views of medium-sized shell and of a large dorsal valve. Respectively from 128 feet above base Keyser limestone, along Penna. R. R. 1 mile south of Dalmatia, Northumberland County, and *R. mutabilis* subzone, Keyser limestone, Mount Rock, Mifflin County.

7a, b. "*Spirifer*" *modestus* Hall. Dorsal and ventral views, 70 to 75 feet above base Keyser limestone, Penna. R. R., south of Mexico, Juniata County.

8a-c. "*Spirifer*" *modestus* var. *plicatus* Maynard. Ventral and side views of transverse shell and ventral view of smaller, ventral valve; 24 and 22 feet, respectively, above base of Keyser limestone, 1 mile north of Selinsgrove Junction, Northumberland County.

9. "*Spirifer vanuxemi* Hall. Incomplete ventral valve; 45 feet below top Keyser limestone, ½ mile east of Hollidaysburg, Blair County.

10a-d. *Merista typa* (Hall). 10a-c, ventral, dorsal and posterior views, the umbo slightly broken, showing part of internal, curved plate; loose material, near middle Keyser limestone, north bank Juniata River opposite Mount Union, Mifflin County. 10d, weathered interior, posterior part ventral valve, showing portion of characteristic "shoe-lifter" process; *M. typa* subzone, Keyser limestone, west slope Little Mountain west of Monterey, Va.

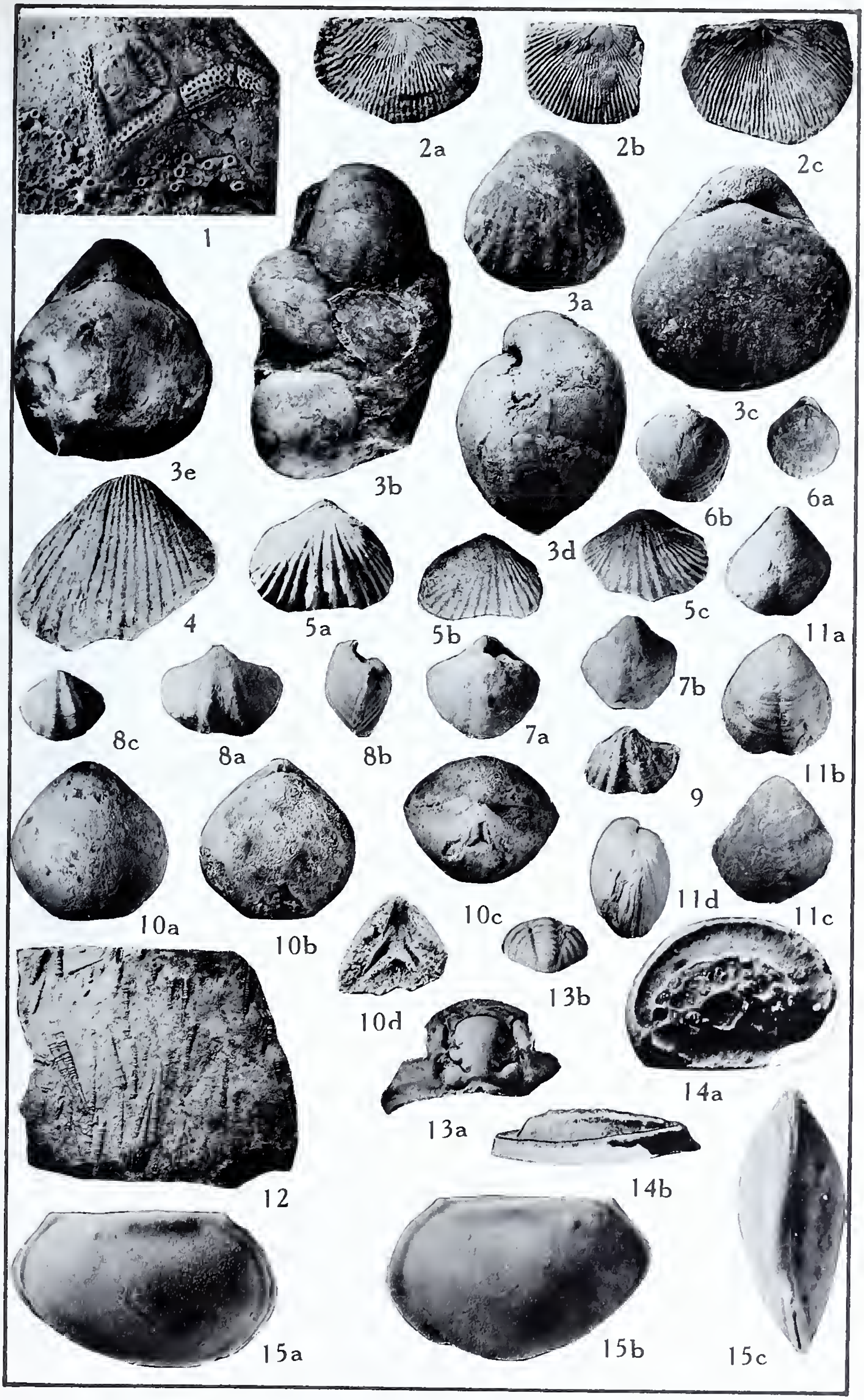
11a-d. *Meristella praenuntia* Schuchert. Three ventral and a side view. Note variations. 11a, c from 135 feet above base Keyser limestone, Penna. R. R., 1 mile south of Dalmatia, Northumberland County. 11b, d, 25 feet below top Keyser limestone, Penna. R. R. south of Mexico, Juniata County.

12. *Tentaculites gyracanthus* (Eaton). Slab with numerous specimens from 35 feet below top Keyser limestone, Clarks Mill, Perry County.

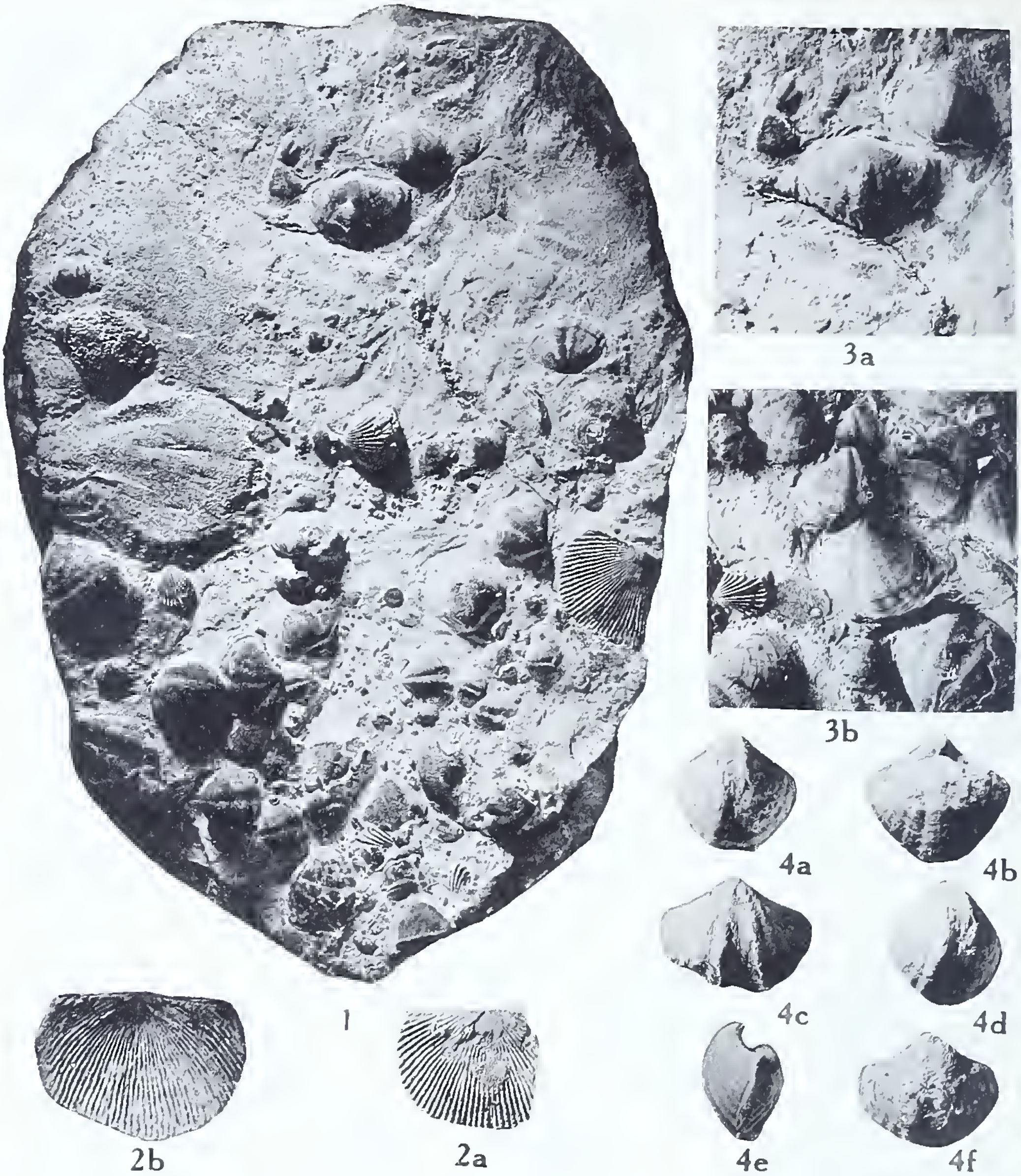
13a-b. *Calymene camerata* Conrad. Imperfect cranidium and small pygidium; *Calymene camerata* subzone, middle Keyser limestone near top Dyson and Rice quarry, Landisburg, Perry County.

14a, b. *Octonaria altoonensis* Swartz. Side and ventral views, holotype, x 29; 38 feet below top Keyser limestone, section opposite Beth Isreal Temple, Altoona, Blair County.

15a-c. *Leperditia scalaris* Jones. Left, right and dorsal views of carapace, x 3, showing characteristic dorsal hump of left valve, muscle scar and finely granulose surface; *L. scalaris* subzone, 19 feet above base Keyser limestone, Clarks Mill, Perry County.



KEYSER FOSSILS



COMPARISON OF LOWER KEYSER AND COBLESKILL BRACHIOPODA

PLATE 2

COMPARISON OF LOWER KEYSER AND COBLESKILL BRACHIOPODA.

1. View x 1 of slab from Cobleskill limestone near Schoharie, New York, bearing *Chonetes jerseyensis*, "*Spirifer*" *corallinensis*, *Camarotoechia litchfieldensis*, *Rhynchospira* sp., and ostracoda. The slab was loaned by the New York State Museum, and is the only museum specimen of *Chonetes jerseyensis* from the Cobleskill limestone in the area west of the Helderberg Mountains.

So far as the writer knows, no *C. jerseyensis* from this area has ever been figured. The illustration used by Grabau (N. Y. State Museum, Geology of the Schoharie Valley) and by others is evidently copied from Weller (Pal. N. J. vol. 3 (1903) pl. 20, fig. 16). This figure represents a variety which occurs in the Decker limestone in New Jersey, and in which the post-lateral ribs radiate from the beak, and do not angulate from the hinge as in Weller's figures 12, 15. The latter form is the one which is so characteristic of the lower Keyser in the middle Appalachian region. It should be considered typical *Chonetes jerseyensis;* while the specimens with radiate post-lateral ribs should be regarded as a variety if not a distinct species.

The occurrence of characteristic *C. jerseyensis* in the Cobleskill in its type area in New York is of great interest. The species was first reported in the Cableskill fauna by Schuchert (On the Manlius formation of New York, Amer. Geol., vol. 31, 1903). It was considered by him one of the specially important species for proving the post-Salina age of the "Manlius" (= Cobleskill to Manlius) of central New York, since he had found it to be abundant in the definitely post-Salina "Manlius" (= lower Keyser) of western Maryland (Schuchert, 1900). Hartnagle also published similar conclusions in 1903, and likewise cited *C. jerseyensis* from the Cobleskill.

2a, b. *Chonetes jerseyensis* Weller. Views x 1 of incomplete ventral valve, from 10 feet above base of Keyser limestone, east side of Pine Creek, near Jersey Shore, Pennsylvania; and interior of ventral valve, from *Gypidula prognostica* zone of Keyser limestone, 1 mile north of Selinsgrove Junction, Pennsylvania. These individuals are a little larger than the specimen on the Cobleskill slab, and the anterior curvature of the lateral ribs is a little more distinct.

3a, b. Parts of the Cobleskill slab, slightly enlarged, and showing dorsal and ventral valves of "*Spirifer corallinensis*" Grabau. These specimens fall within the range of characters seen in "*Spirifer*" *modestus* Hall and "*S.*" *modestus* var. *plicatus* Maynard of the lower Keyser (figures 4a-f), and for the most part should be considered synonymous with Maynard's species. However, the classification to be followed requires a further check on the characters of the holotypes of "*S.*" *corallinensis* and "*S.*" *eriensis Grabau*. The Cobleskill specimen of "*Spirifer crispus*" figured by Hall, and cited as the holotype of "*S.*" *corallinensis* by Grabau, is more transverse than the individuals here illustrated, has a narrower and perhaps deeper sinus, and is supposedly devoid of plications." "*S.*" *eriensis*, on the other hand, is plicate, and has a relatively extended ventral beak. Although the specimens on the Cobleskill slab have been regarded as "*S.*" *corallinensis* by members of the New York State Museum, it may prove desirable to consider them, and the plicate Keyser material, to be "*S.*" *modestus var. eriensis.*

4a-f. "*Spirifer*" *modestus* (4a) and var. *plicatus* (4b-f). Views, x 1, of ventral and dorsal aspects of shell from lower Keyser, Mexico, Pa.: of a more and a less transverse ventral valve from lower Keyser, 1 mile north of Selinsgrove Junction, Pa.; and side and ventral aspects of shells, from lower Keyser, Strait Creek, near Monterey, Virginia.

PLATE 3

HELDERBERG

BRACHIOPODA

(Figures x 1, except Fig. 8, x 1/3)

1a-g. *Rhipidomella oblata* (Hall), 1a-d, interiors ventral and dorsal valves of completely silicified shell and dorsal and side views of same, articulated; lower 5 feet New Scotland cherty limestone, old quarries, Stillwell Ridge, 2½ miles south of Needmore, Fulton County. 1e, interior of silicified ventral valve; loose, New Scotland cherty limestone, Stillwell Ridge, 3 miles south of Needmore, Fulton County. 1f, incomplete internal mold, ventral valve; upper part Falling Springs sandstone, Falling Springs, Perry County. 1g, internal mold, ventral valve with relatively weak muscle scars; New Scotland limestone, Mount Rock, Mifflin County.

2. *Rhipidomella musculosa* Hall. Internal mold, ventral valve; 1 foot below top Port Ewen shale, R. R. cut, north side Brodhead Creek east of Minisink Mills, Monroe County.

3a, b. *Isorthis perelagans* (Hall). Internal mold, ventral valve; 1 foot below top Port Ewen shale, R. R. cut, north side Brodhead Creek, east of Minisink Mills, Monroe County.

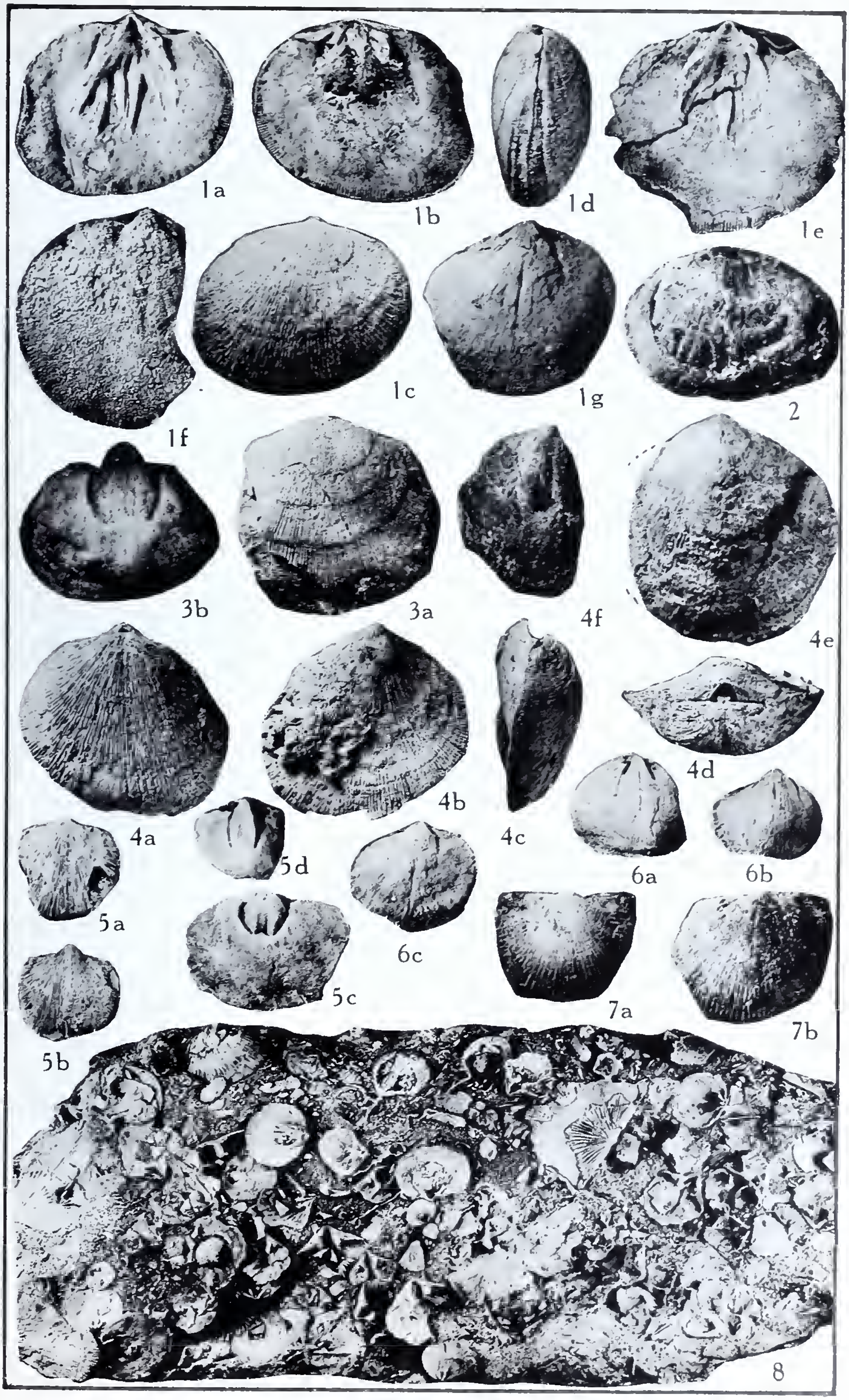
4a-f. *Isorthis* (?) *eminens* (Hall). 4a-d, dorsal, ventral, side and posterior views, silicified shell showing erect ventral beak, high cardinal area, median sulcus of posterior part dorsal valve. Hinge is narrower, and this specimen might well be referred to *Orthis peduncularis* Hall. Basal part cherty New Scotland limestone, ¼ mile southeast Warfordsburg, Fulton County. 4e and f, incomplete ventral valve and incomplete mold of ventral valve; 1 foot above top Coeymans sandstone, souht side Licking Creek near Warren Point, Franklin County.

5a-d. *Levenea subcarinata* (Hall). 5a, b, incomplete dorsal and ventral valves; basal Becraft limestone, road over "hogback" near Decker Ferry, Monroe County. 5c, internal mold ventral valve; 2 feet above base Mandata shale, Neelyton, Huntingdon County. 5d, incomplete internal mold ventral valve, somewhat squeezed, so that muscle scar appears relatively long and narrow; 31 feet below top Mandata shale, ¼ mile south of Dalmatia, Northumberland County.

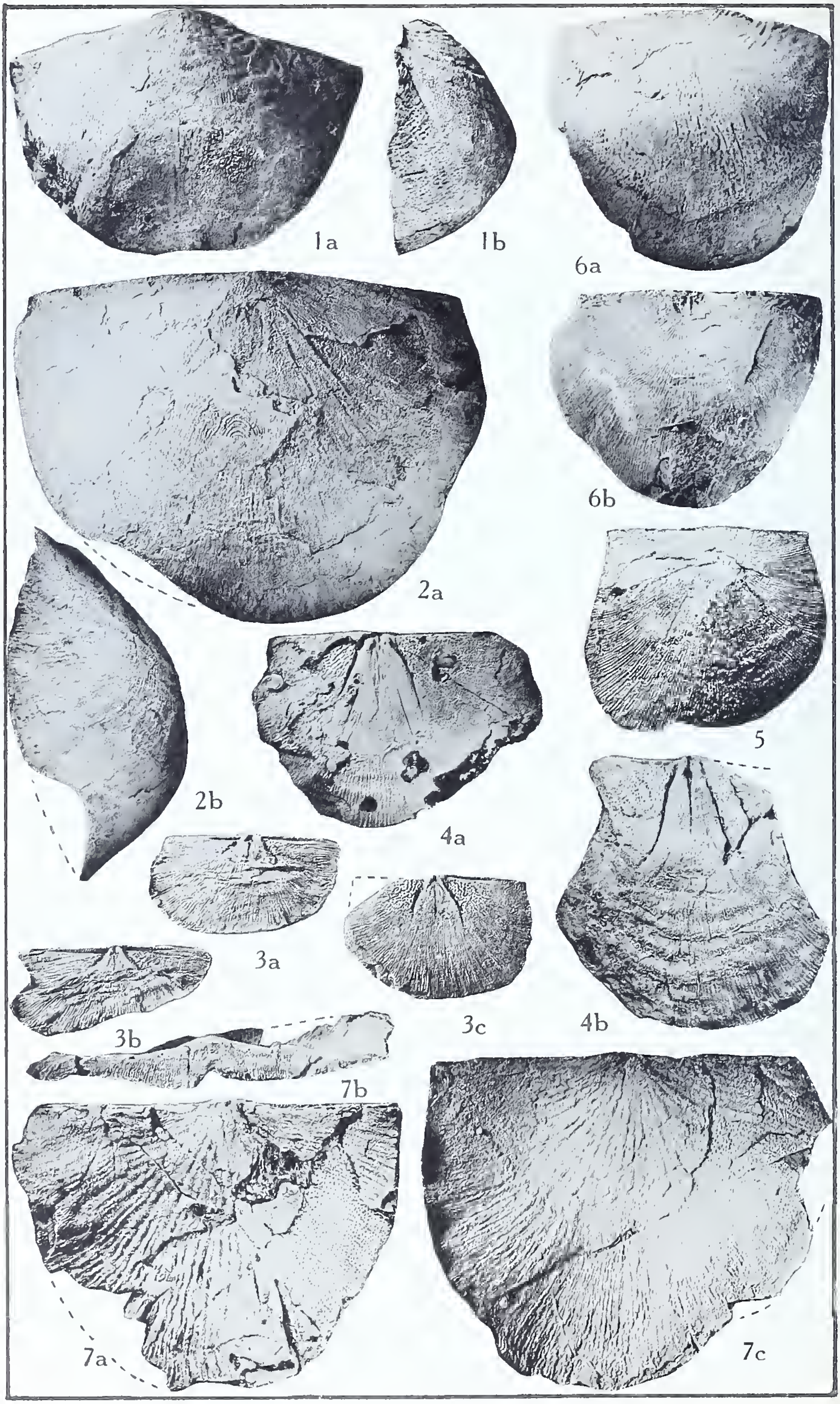
6a, c. *Platyorthis planoconvexa* (Hall). 6a, b, internal molds of two dorsal valves; 60-90 feet below top Port Ewen shale, R. R. cut north side Brodhead Creek, east of Minisink Mills, Monroe County. 6c, internal mold, ventral valve; 31 feet below top Mandata shale and chert; ¼ mile south of Dalmatia, Northumberland County.

7a, b. *Stropheodonta varistriata* (Conrad). Two ventral valves; Coeymans limestone; 1 mile south of Curtin, Centre County.

8. *Rhipidomella oblata*, *Strophonella undaplicata*, *Meristella arcuata*. Under surface of chert slab bearing silicified valves, concave side down; 2 feet below base of New Scotland limestone; Stillwell Ridge, 3 miles south of Needmore, Fulton County.



HELDERBERG BRACHIOPODA



HELDERBERG BRACHIOPODA

PLATE 4

HELDERBERG

BRACHIOPODA

(All figures x 1)

1a, b. *Leptaena ventricosa* (Hall). Ventral and side views, ventral valves, upper part Licking Creek limestone; along R. R. 1 mile northeast of Clifton Forge, Va., and 105 to 110 feet above top New Scotland cherty limestone; ½ mile east of Monterey, Va.

2a, b. *Leptostrophia magniventroides* Swartz n. sp. Ventral and side views, holotype, a large ventral valve, shell partly broken away. Species differs from *L. magniventra* (Hall) as follows: Ventral area somewhat lower, so that angle across beak measures 166° in type, compared with 137°, 153°, 161° and 147° in specimens figured by Hall. Ventral muscle scars smaller, less strongly impressed; radial striae not obsolete on dorsal valve, but about as strong as those on ventral valve. On holotype, there are about 11 low, rounded striae in 5 mm., separated by wide, flat interspaces. Concavity of associated dorsal valves about 5 to 12 mm. Licking Creek limestone, 105 to 110 feet above top cherty New Scotland limestone; ½ mile east of Monterey, Va.

3a-c. *Leptostrophia oriskania* Clarke. Distorted, internal molds of 2 ventral valves; 60 to 90 feet below top Port Ewen shale, R. R. cut north side Brodhead Creek, east of Minisink Mills, Monroe County. 3c, internal mold ventral valve, Mandata (c) shale and chert; north bank Potomac River in cut on W. M. R. R., Tonoloway Ridge, Md.

4a, b. *Leptostrophia beckii* (Hall). Internal molds ventral valves. Respectively from 5 feet above base Mandata shale, Penna. R. R. south of Mexico, Juniata County, and 2 feet above base Mandata (?) shale and chert, north bank Potomac River, cut on W. M. R. R., Tonoloway Ridge, Md.

5. *Leptostrophia blainvillei* Billings. Ventral valve with part of shell broken away showing muscle scars. Note posterior curvature of striae near hinge; upper part Licking Creek limestone north side Licking Creek, east of Warren Point, Franklin County.

6a, b. *Strophonella leavenworthana* (Hall). 6a, exfoliated exterior dorsal valve, 2 feet above base New Scotland limestone, Penna. R. R. south of Mexico, Juniata County. 6b, external mold ventral valve, retaining part of shell; Coeymans limestone, D. Helman quarry, ½ mile east of New Paris, Bedford County.

7a-c. *Stropheonella undaplicata* C. K. Swartz. Two silicified and in part exfoliated ventral valves, with posterior view of first. Costellae coarse near umbo and become finer toward margin, as in type, but are less sinuous, and do not seem to reunite. From lower 5 feet of New Scotland limestone, old quarries on Stillwell Ridge, 2½ miles south of Needmore, Fulton County.

PLATE 5

HELDERBERG

BRACHIOPODA

(Figures x 1, except as noted)

1a-e. *Schuchertella woolworthana* (Hall). 1a, exterior ventral valve; 5 feet above base New Scotland limestone, ½ mile east of Hollidaysburg, Blair County. 1b, internal mold large ventral valve; near top Falling Springs sandstone, Falling Springs, Perry County. 1c, dorsal valve of variety not flattened toward umbo as in typical material; Coeymans limestone, Hoover Quarry, Bedford Quadrangle, Bedford County. 1d, e, interior of ventral valve and exterior of dorsal of smaller variety; very fossiliferous New Scotland shale near Decker Ferry, Monroe County.

2a-f. *Gypidula coeymanensis* Schuchert. 2a-c, dorsal and side views of two shells and interior of weathered, unbonal part of a ventral valve; Coeymans limestone, R. R. cut on north side Brodhead Creek, east of Minisink Mills, Monroe County. 2d, e, exterior of ventral valve and side view of weathered interior of shell embedded in limestone, preserving spondylium and other internal structures; 0 to 3 feet above base Coeymans limestone, 1 mile south of Curtin, Centre County. 2f, interior of weathered unbonal part of ventral valve; loose from Coeymans beds, Clarks Mill, Perry County.

3a, b. *Chonetes pustulocristata* Swartz, n. sp. 3a, holotype, incomplete internal mold or ventral valve retaining some of shell. Specimen shows impression of pustulose internal ridges, close to and nearly parallel with hinge. On this and associated specimens, there are 4 to 6 rather small, cardinal spines; about 6 to 7 radial striae in 2 mm, and 14 to 15 concentric striae in 1 mm. Externally, species suggests *Chonetes hudsonicus* Clarke. Licking Creek limestone, 130 feet above top New Scotland limestone, ½ mile east of Monterey, Va. 3b, internal mold ventral valve, showing impression of pustulose ridges; loose from Mandata (?) shale and chert, top of Tonoloway Ridge, just south of Tonoloway Creek, 3 miles west of Hancock, Md.

3c. *cf. Chonetes aroostookensis* Clarke. Exterior of incomplete ventral valve. Specimen preserves bases of 5 cardinal spines; 1 foot below top Port Ewen shale, N. Y. S. and W. R. R. cut, north side Brodhead Creek, east of Minisink Mills, Monroe County.

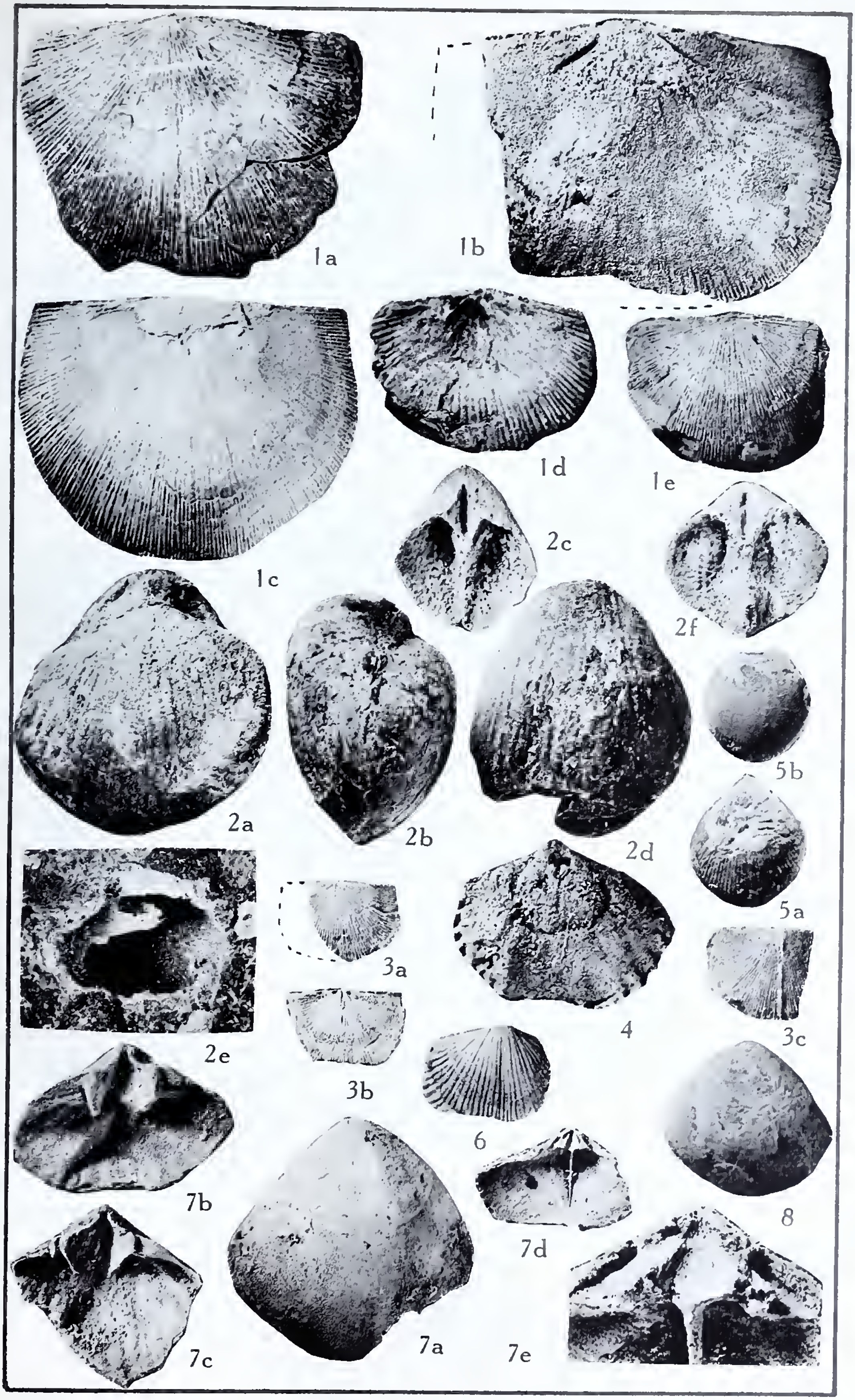
4. *Eatonia medialis* (Vanuxem). Internal mold ventral valve; Falling Springs sandstone on slabs with *Eospirifer macropleurus;* Clarks Mill, Perry County.

5a, b. *Rensselaeria subglobosa* Weller. 5a, ventral view; top of exposed *Synphoria (Dalmanites) dentatus* zone, back of Dalton Nearpass farm, 1½ miles south of Port Jervis, N. Y. 5b, incomplete dorsal valve; Licking Creek limestone, 65 feet above top New Scotland limestone, south side Licking Creek, east of Warren Point, Franklin County.

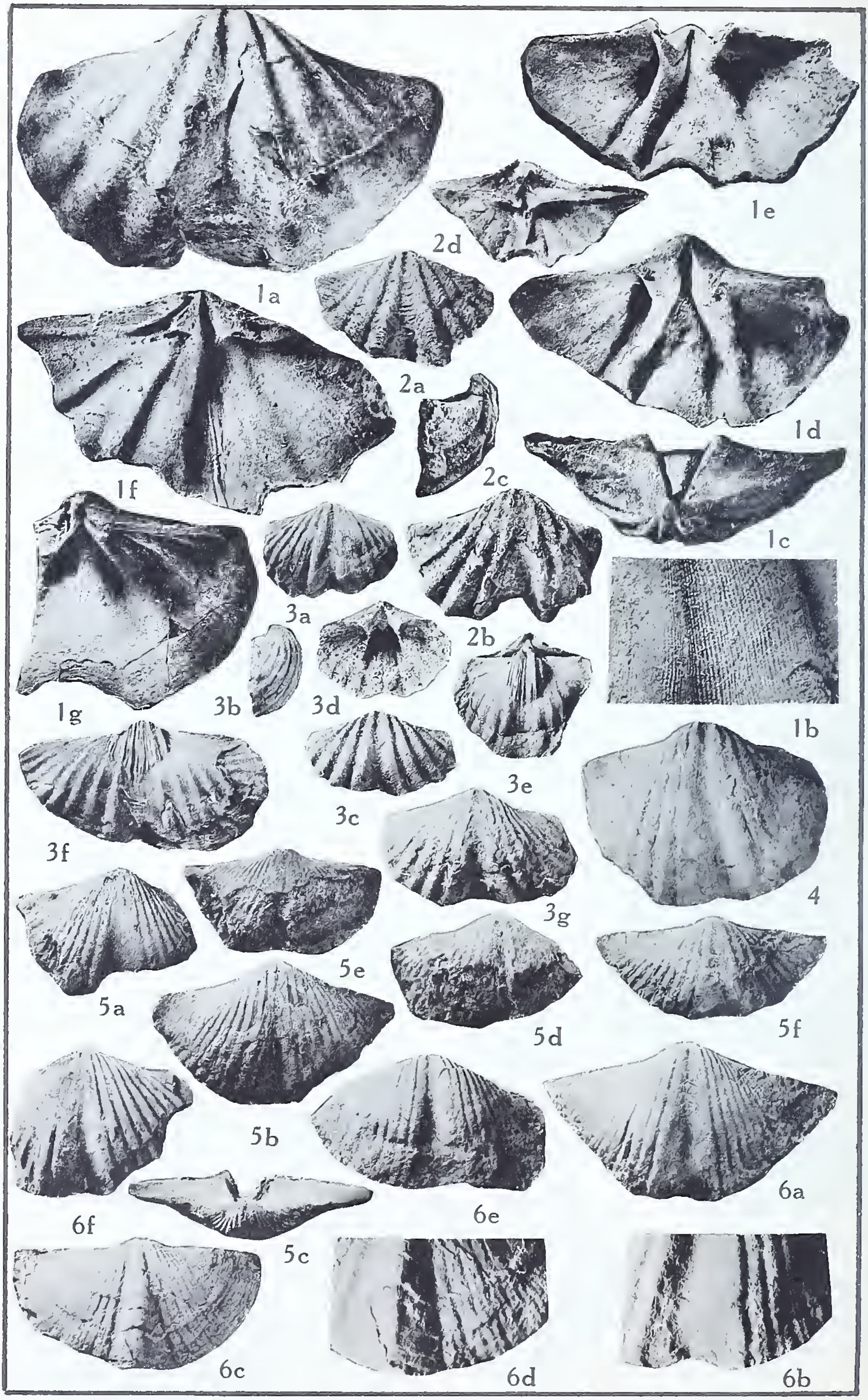
6. *Trematospira multistriata* Hall. Squeeze from mold of ventral valve; 45 feet above base Mandata shale and chert, ¼ mile south of Mandata, Northumberland County.

7a-e. *Meristella arcuata* (Hall). 7a, exterior ventral valve suggestive of material separated as *M. subquadrata* by Hall. 7b, c, interiors, silicified umbonal parts, ventral valves. 7d, e, interiors, silicified umbonal parts dorsal valves, the second x 3. 7a, c, loose from New Scotland limestone, quarries on Stillwell Ridge, 2½ miles south of Needmore, Fulton County. 7b, d, e, lower 5 feet New Scotland limestone, same locality.

8. *cf. Meristella lata* (Hall). Ventral valve small specimen close to Oriskany species; 5 to 10 feet below top Licking Creek limestone, south side Licking Creek, east of Warren Point, Franklin County.



HELDERBERG BRACHIOPODA



HELDERBERG BRACHIOPODA

PLATE 6

HELDERBERG

BRACHIOPODA

(Figures x 1, except as noted)

1a-g. *Eospirifer macropleurus* (Conrad). 1a, ventral valve; New Scotland limestone, ½ mile east of Hollidaysburg, Blair County. 1b, detail of part of surface ventral valve, x 3; New Scotland limestone, Stillwell Ridge, 2½ miles south of Needmore, Fulton County. 1c-e, posterior and two interior views, the last tilted, incomplete, silicified ventral valve; lower 5 feet New Scotland limestone, same locality as 1b. 1f, g, interior views incomplete, silicified dorsal and ventral valves, showing characteristic features; loose from New Scotland limestone, ½ mile east of Monterey, Va.

2a-d. "*Spirifer*" *perlamellosus* Hall. 2a, exterior silicified ventral valve, showing strong concentric lamellae; loose from New Scotland limestone, ½ mile east of Monterey, Va. 2b, c, ventral and side views ventral valve with concentric lamellae less well preserved; 2 feet above base New Scotland limestone, Penna. R. R. south of Mexico, Juniata County. 2d, interior of silicified ventral valve showing strong median septum; Hillegas quarry, 2½ miles east of New Paris, Bedford County.

3a-g. "*Spirifer*" *cyclopterus* Hall. 3a, b, ventral and side views ventral, valve from very fossiliferous New Scotland shale at "5 loaves of bread," along Wallpack Bend, Delaware River, Monroe County. 3c, ventral valve showing fine concentric striae; base of New Scotland limestone, ridge ½ mile east of Warfordsburg, Fulton County. 3d, interior view, silicified ventral valve; loose from New Scotland limestone ½ mile east of Monterey, Va. 3e, f, internal molds ventral valves; 62 and 32 feet above base Mandata shale and chert, ¼ mile south of Mandata, Northumberland County. 3g, larger ventral valve, Licking Creek limestone, east of Warren Point, Franklin County.

4. "*Spirifer*" sp. This is a large and more convex variety of "*S.*" *cyclopterus*, approaching Oriskany *S. murchisoni* (Castlenau) and especially *S. perdewi* Schuchert; Licking Creek limestone, 60 to 65 feet above top New Scotland limestone, south side Licking Creek, east of Warren Point, Franklin County.

5a-f. "*Spirifer*" *concinnus* Hall. 5a, ventral valve; 10 feet below top Becraft limestone, West Shore R. R. about 2,000 feet south of bridge over Rondout Creek, Kingston, N. Y. 5b, c, ventral and tilted posterior views of ventral valve, approaching "*S.*" *aroostookensis;* 2 to 4 feet above base Mandata (?) shale, south side Licking Creek, east of Warren Point, Franklin County. 5d, ventral valve; 1 foot below top Port Ewen shale, N. Y. S. and W. R. R. cut, north side Brodhead Creek, east of Minisink Mills, Monroe County. 5e, f, transverse ventral valves, representing a variety of this species; *Synphoria (Dalmanites) dentatus* zone, old Coos, now Douglas farm, Peters Valley, N. J., and back of Dalton Nearpass farm, 1½ miles south of Port Jervis, N. Y.

6a-f. "*Spirifer*" *aroostookensis* Clarke. 6a-d, ventral and dorsal valves, with enlargements x 1½ of part of surface of each. This is essentially a variety of "*S.*" *concinnus*, somewhat more transverse and with a few more plications, further distinguished by the grooving of the ribs. 6e, ventral valve, somewhat distorted. 5 to 10 feet below top Licking Creek limestone, south side Licking Creek, east of Warren Point, Franklin County. 6f, incomplete, ventral valve; 1 foot below top Port Ewen shale, N. Y. S. and W. R. R. cut, north side Brodhead Creek, east of Minisink Mills, Monroe County.

PLATE 7

HELDERBERG

TRILOBITA

(Figures x 1, except as noted)

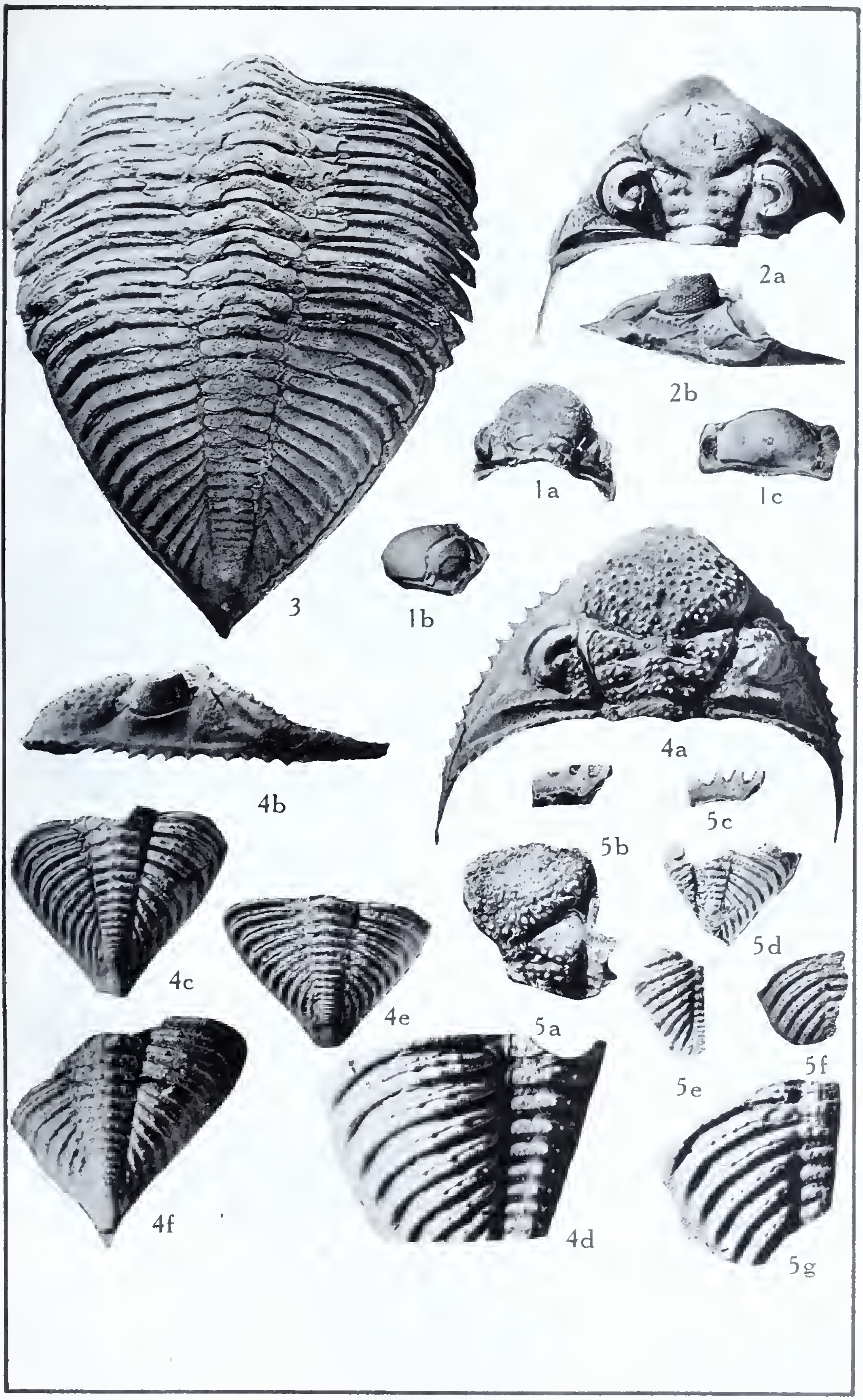
1a-c. *Phacops logani* Hall. Dorsal side and anterior views nearly complete cephalon; New Scotland limestone, 5 feet above base of Coeymans limestone, 1 mile south of Curtin, Centre County.

2a, b. *Synphoria* sp. Dorsal and side views of fairly complete cephalon. This species is suggestive of *Dalmanites griffoni* Clarke of the St. Albans beds of the Gaspé region. The snout is shorter, and there are various differences in proportions. Unfortunately, finer details of ornamentation not described by Clarke. From Coeymans limestone, Hoover quarry, rectangle coördinate 58553 or Bedford quadrangle, Bedford County.

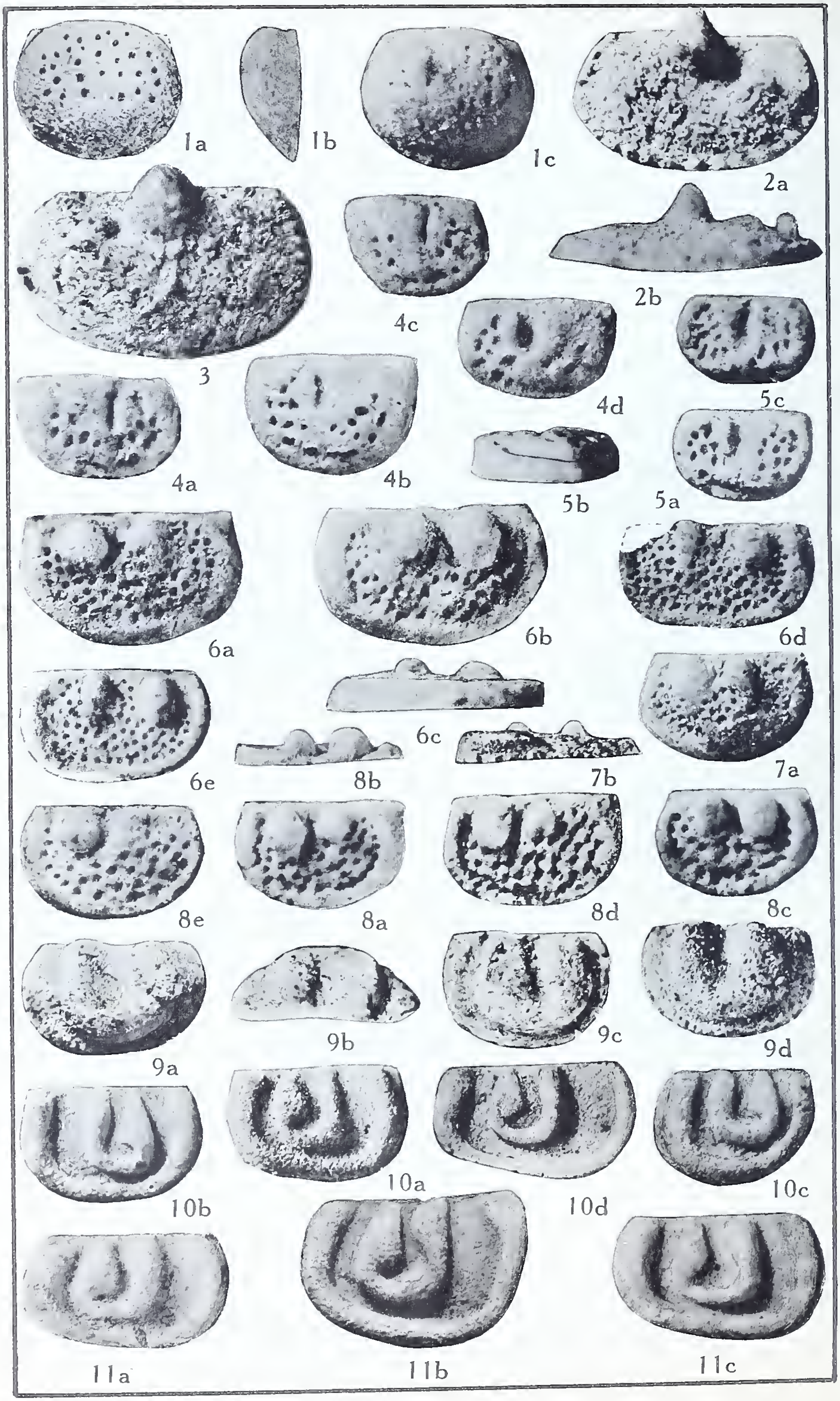
3. *Synphoria (?) micrurus* (Green). Pygidium and most of thorax; Coeymans limestone, quarry near New Paris, Bedford County.

4a-f. *Synphoria dentatus* Barrett. 4a, b, dorsal and side views of nearly complete cephalon. 4c-e, three pygidia with parts of first enlarged x 2 for comparison with 5g; *Synphoria (Dalmanites) dentatus* zone, Wallpack Ridge, back of present Dalton Nearpass farm, and about ½ mile north of old William Nearpass quarries, N. J.

5a-g. *Synphoria dentatus* (Barrett). Fragmentary material on which is based identification of this species in Licking Creek limestone near Monterey, Va. 5a, part of cranidium showing characteristic pustulation of surface. 5b, c, two views of fragment of doublure, preserving marginal spines. 5d-g, fragmentary pygidia, 5g being an enlargement x 2 of 5f, for comparison with 4d. From Licking Creek limestone, 105 to 110 feet above top cherty New Scotland limestone, ½ mile east of Monterey, Va. It is hoped that further collecting in the Monterey region will bring to light more perfect specimens of this interesting trilobete.



HELDERBERG TRILOBITA



SHRIVER OSTRACODA

PLATE 8

SHRIVER

OSTRACODA

1a-c. *Paraschmidtella dorsopunctata* Swartz. Squeeze from external mold, and posterior and side views natural internal mold of holotype, representing a left valve, x 30; *Metaplasia plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

2a, b. *Aechmina bigeneris* Swartz. Side and ventral views of squeezes from holotype, an external mold of left valve, x 30; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

3. *Aechmina spinoterminata* Swartz. Side view of squeeze from holotype, an external mold of right valve, x 30; Shriver chert, east side Pine Creek, near Jersey Shore, Lycoming County.

4a-d. *Pyxiprimitia ventripunctata* Swartz. 4a, squeeze from holotype, an external mold of right valve, x 30. 4b-d, squeezes from molds of left, right and left valves; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

5a-c. *Pyxiprimitia ventriclefta* Swartz. Views of squeezes from two of syntypes, x 30. 5a, b, side and ventral views of squeeze from external mold, left valve. 5c, side view of squeeze from mold of right valve. From 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

6a-e. *Ulrichia pluripunctata* Swartz. 6a-c, squeezes from two of syntypes, natural, external molds of left and right valves with ventral view of second squeeze, x 30; trilobite bed of upper part Shriver chert, 1 mile south of Curtin, Centre County. 6d, e, squeezes from natural molds of two right valves; 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

7a, b. *Ulrichia terminata* Swartz. Side and ventral views of squeeze from holotype, an external mold, left valve. This may prove to be a dimorph of associated *U. pluripunctata;* 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

8a-e. *Ulrichia affinis* Bassler and Kellett. Side views of squeezes from molds of three left valves and one right with dorsal view of the first squeeze, x 30; *M. plicata* zone of Shriver chert, 1 mile south of Curtin, Centre County.

9a-d. *Bollia cristata* Swartz. 9a, b, side and dorsal views of squeeze from holotype, a mold of right valve, x 22; Shriver chert near Jersey Shore, Lycoming County. 9c, d, squeezes from molds of two right valves, x 22; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

10a-c. *Bollia sagittaformis* Swartz. 10a, squeeze from one of syntypes, a mold of left valve, x 15; *M. plicata* zone of Shriver chert, 1 mile south of Curtin, Centre County. 10b, c, squeezes from molds of right valves, the latter distorted, x 15. 10d, squeeze from mold of left valve of elongate variety, x 13; *M. plicata* zone, Shriver chert, Mount Rock, Mifflin County.

11a-c. *Bollia burgeneri* Swartz. 11a, squeeze from one of syntypes, a mold of left valve, x 15; 70 feet above base of Shriver chert, Mount Rock, Mifflin County. 11b, c, squeezes from molds of two left valves; Shriver chert near Altoona, Blair County, and *M. plicata* zone at Mount Rock, Mifflin County.

PLATE 9

SHRIVER

OSTRACODA

1a-d. *Bollia zygocornis* Swartz. 1a-c, side and dorsal views of squeezes from holotype, mold of right valve, x 15, and detail of surface of anterior knob of inner ridge of same, x 40; Shriver chert, near Jersey Shore, Lycoming County. 1d, natural, internal mold of left valve, x 15; trilobite bed, near top Shriver chert, Mount Rock, Mifflin County.

2a, b. *Parabolbina limbata* Swartz. 2a, squeeze from holotype, mold of right valve, x 30. 2b, squeeze from mold of left valve of the frill-less dimorph, presumably male, x 30; 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

3a, b. *Kirkyella ventricosa* (Swartz). 3a, squeeze from holotype, mold of left valve, x 30. 3b, natural, internal mold of left valve, x 30; *M. plicata* zone of Shriver chert, 1 mile south of Curtin, Centre County.

4a-e. *Thlipsura confluens* Swartz. 4a, b, d, squeezes from molds of two right valves with posterior view of second, x 15. The second preserves part of edge of opposite valve; also the ridge bounding terminal, depressed area is continued dorsally, separating terminal depression from the ∩-shaped furrow. 4c, e, posterior view of left valve, and dorsal view of carapace, x 15, orientiation here used for these thlipsurids is based on supposition that greatest thickness is behind middle of carapace. 4a, e, from 67 feet above base Shriver chert, Mount Rock, Mifflin County, others from 90 to 110 feet above base Shriver chert, ½ mile east of Hollidaysburg, Blair County.

5a-c. *Thlipsura tricornis* Swartz. Squeezes from molds of two left valves, and posterior view of squeeze from imperfect mold of a carapace, x 15. 5a, from Shriver chert, near Altoona, Blair County; 5b, c, from 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

6a, b. *Thlipsura robusta* (Ulrich and Bassler). Side and posterior views of squeezes from molds of two right valves, x 15; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County, and 67 feet above base Shriver chert, Mount Rock, Mifflin County.

7a, b. *Thlipsurella oblonga* (Ulrich and Bassler). Side and dorsal views of squeezes from mold of left valve, x 29; 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

8a, b. *Thlipsurella orthoclefta* Swartz. Side and ventral views of squeezes from holotype, mold of right valve, x 29; Shriver chert near Altoona, Blair County.

9. *Thlipsurella crateriformis* Swartz. Squeeze from holotype, mold of right valve, x 29; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

10a-d. *Thlipsurella secoclefta* Swartz. 10a, b, side and dorasl views of squeeze from holotype, mold of right valve, x 29; 105-110 feet above base Shriver chert, Mount Rock, Mifflin County. 10c, d, squeezes from molds of two left valves from a variety with two anterior pits, x 29; Shriver chert.

11. *Thlipsurella ellipsoclefta* Swartz. Squeeze from holotype, mold of left valve, x 29; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

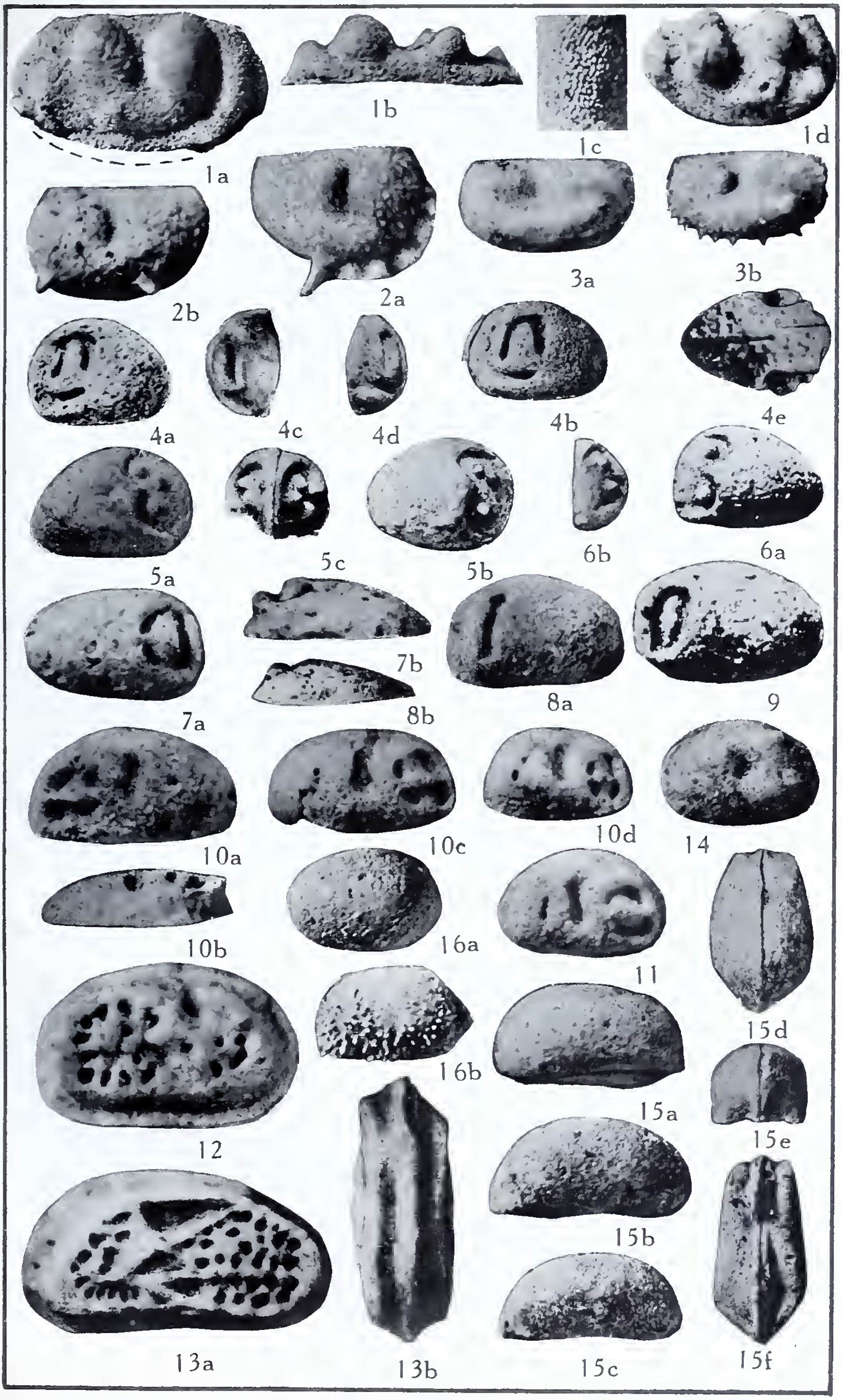
12. *Octonaria dorsosulcata* Swartz. Squeeze from holotype, mold of left valve, retaining part of edge of opposite valve, x 29; 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

13a, b. *Octonaria deltisulcata* Swartz. 13a, squeeze from holotype, mold of right valve, x 29. 13b, dorsal view of squeeze from mold of part of a carapace, posterior end above, x 29; 90 to 110 feet above base of Shriver chert, ½ mile east of Hollidaysburg, Blair County.

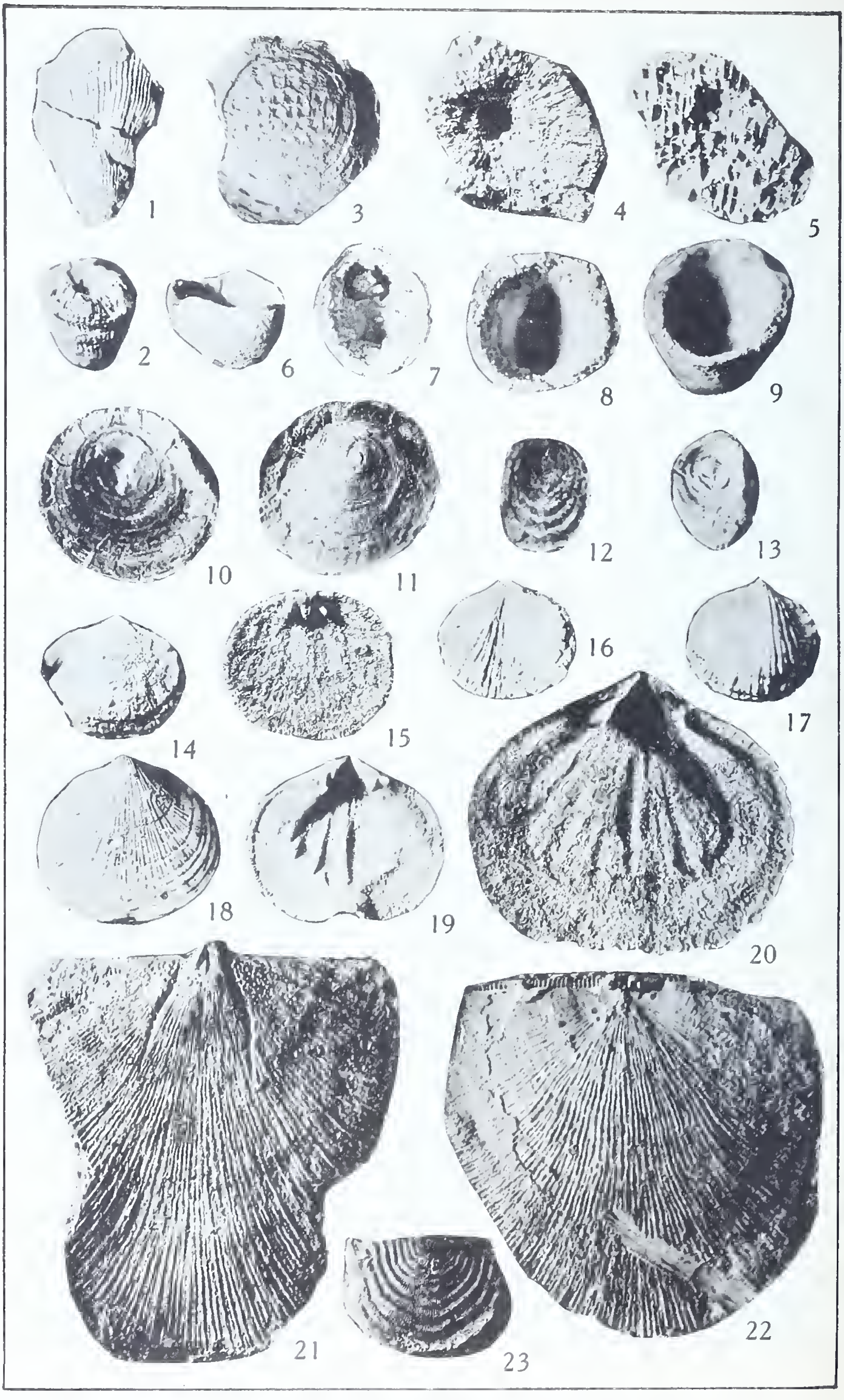
14. *Parahealdia centralis* Swartz. Side view of holotype, internal mold of left valve, x 45; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.

15a-f. *Acanthoscapha pentagonalis* Swartz. 15b, c, side view of squeeze from external mold, and side view of internal mold of holotype, the molds of a right valve, x 15. The latter shows impression of muscle scar; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County. 15a, squeeze from mold of left valve, x 15; 59 feet above base of Shriver, Mount Rock, Mifflin County. 15d, e, dorsal and anterior views of squeeze from mold of carapace, x 15, same horizon and locality. 15f, squeeze from impression of ventral surface of carapace, x 15; *M. plicata* zone south of Curtin, Centre County.

16a, b. *Tubulibairdia tubulifera* Swartz. Squeeze from external mold of left valve, and internal mold of left valve, x 15; *M. plicata* zone, Shriver chert, 1 mile south of Curtin, Centre County.



SHRIVER OSTRACODA



ORISKANY COELENTERATA, ECHINODERMATA AND BRACHIOPODA

PLATE 10

Oriskany

COELENTERATA, ECHINODERMATA AND BRACHIOPODA

COELENTERATA

1. *Zaphrentis* sp. ind. lateral aspect x ½, Ridgeley, Union County.

2. *Z. roemeri* M. Edwards and Haime, lateral aspect x 1, Ridgeley, Perry County.

3. *Favosites shriveri* (Herzer), base x 1, Ridgeley, Perry County.

4. *F. conicus* Hall, superior view x ½, Ridgeley, Bedford County.

5. *F. conicus* Hall, lateral view x ¾, Ridgeley, Bedford County.

ECHINODERMATA

6. *Edriocrinus sacculus* Hall, lateral view of calyx x ⅔, Ridgeley, Bedford County.

7. *E. sacculus* Hall, superior view of calyx x ⅔, Ridgeley, Bedford County.

8. *E. pociliformis* Hall, superior view of calyx x 2, Ridgeley, Bedford County.

9. *E. pociliformis* Hall, lateral view of calyx x 2, Ridgeley, Bedford County.

BRACHIOPODA

10. *Orbiculoidea jervensis* Barrett, dorsal valve x ¾, Shriver, Blair County.

11. *O.* cf. *jervensis* Barrett, dorsal valve x 1, Shriver, Mifflin County.

12. *Pholidops multilamellosa* Schuchert, dorsal valve x 3, Shriver, Huntingdon County.

13. *P. multilamellosa* Schuchert, ventral valve x 3, Shriver, Huntingdon County.

14. *Platyorthis planoconvexa* (Hall), ventral valve x 1, Ridgeley, Bedford County.

15. *P. planoconvexa* (Hall), dorsal valve, interior x 1, Ridgeley, Bedford County.

16. *Anoplotheca dichotoma* (Hall), dorsal valve, exterior x ¾, Ridgeley, Snyder County.

17. *A. dichotoma* (Hall), ventral valve x ¾, Ridgeley, Snyder Couty.

18. *Rhipidomella musculosa* (Hall), ventral valve x 1, Shriver, Centre County.

19. *R. musculosa* (Hall), ventral valve, interior x 1¼, Shriver, Centre County.

20. *R. musculosa* (Hall), ventral valve, interior x 1½, Ridgeley, Bedford County.

21. *Stropheodonta arctimuscula* Schuchert, ventral valve, interior x 2, Shriver, Northumberland County.

22. *S. arctimuscula* Schuchert, dorsal valve, exterior x 2, Shriver, Northumberland County.

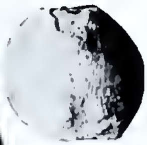
23. *Leptaena rhomboidalis* (Wilckens), ventral valve x 1, Shriver, Juniata County.

PLATE 11

Oriskany

BRACHIOPODA (Continued)

1. *Atrypa reticularis* (Linnaeus), ventral valve x ½, Ridgeley, Perry County.
2. *Rensselaeria marylandica* Hall, dorsal valve, internal cast x 1½, Ridgeley, Mifflin County.
3. *R. ovoides* (Eaton), dorsal valve, internal cast x 1¼, Ridgeley, Perry County.
4. *Elytha saffordi* Hall, ventral valve x ⅔, Shriver, Juniata County.
5. "*Spirifer*" *arenosus* (Conrad), dorsal valve x ⅔, Ridgeley, Franklin County.
6. "*S.*" *arenosus* (Conrad), ventral valve, interior x ¾, Ridgeley, Bedford County.
7. "*S.*" *arenosus* (Conrad), dorsal valve, interior x ¾, Ridgeley, Bedford County.
8. "*S.*" *tribulis* Hall, ventral valve x 2, Ridgeley, Perry County.
9. "*S.*" *murchisoni* Castlenau, ventral valve x 1, Ridgeley, Union County.
10. "*S.*" *murchisoni* Castlenau, dorsal valve x ½, Ridgeley, Union County.
11. *Trematospira multistriata* (Hall), dorsal valve x 1, Shriver, Juniata County.
12. *Metaplasia plicata* Weller, ventral valve x 1½, Shriver, Juniata County.
13. *M. plicata* Weller, dorsal valve x 1½, Shriver, Juniata County.
14. *Cyrtina rostrata* (Hall), ventral valve x 1, Ridgeley, Perry County.
15. *C. rostrata* (Hall), dorsal valve x 1, Ridgeley, Perry County.
16. *Anoplotheca flabellites* (Conrad), ventral valve x 1½, Ridgeley, Montour County.
17. *A. fimbriata* (Hall), ventral valve x 2, Ridgeley, Bedford County.
18. *A. concava* (Hall), ventral valve x 2, Ridgeley, Perry County.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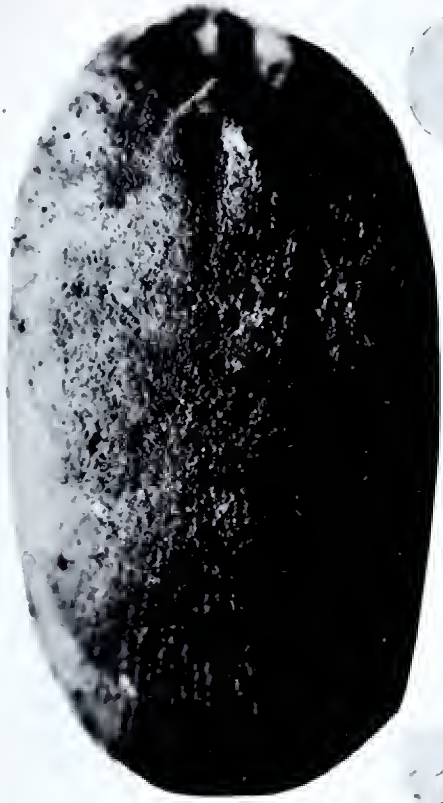
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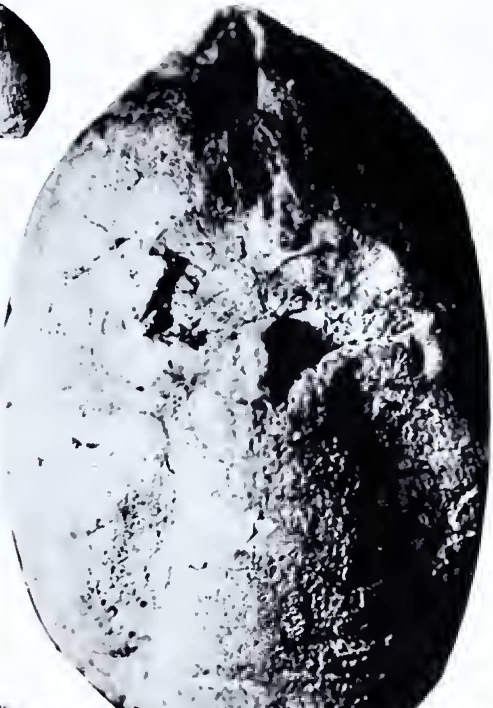
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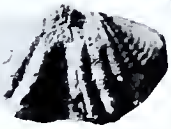
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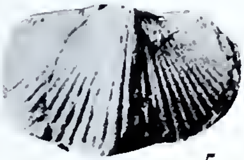
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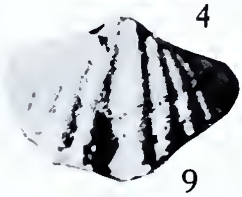
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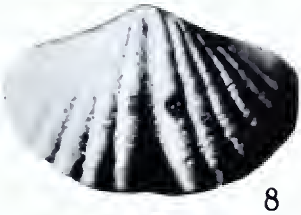
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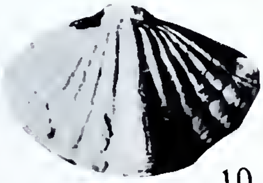
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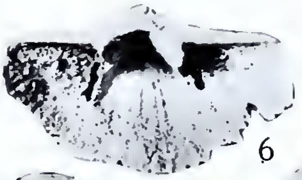
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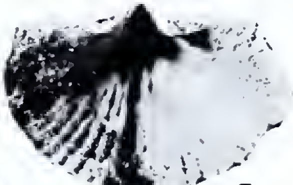
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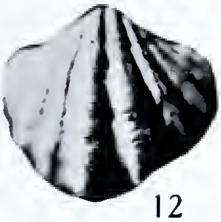
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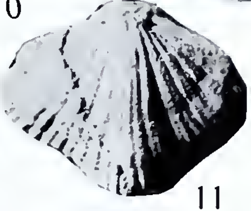
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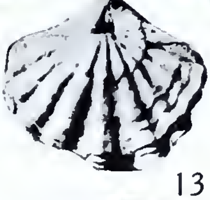
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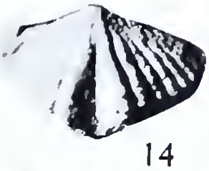
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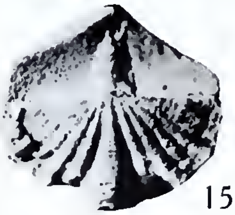
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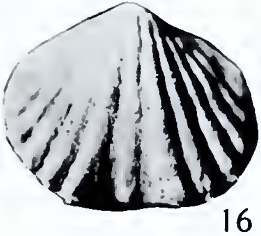
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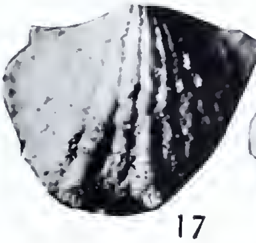
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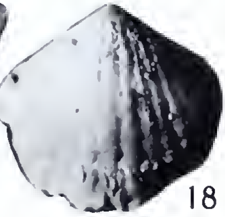
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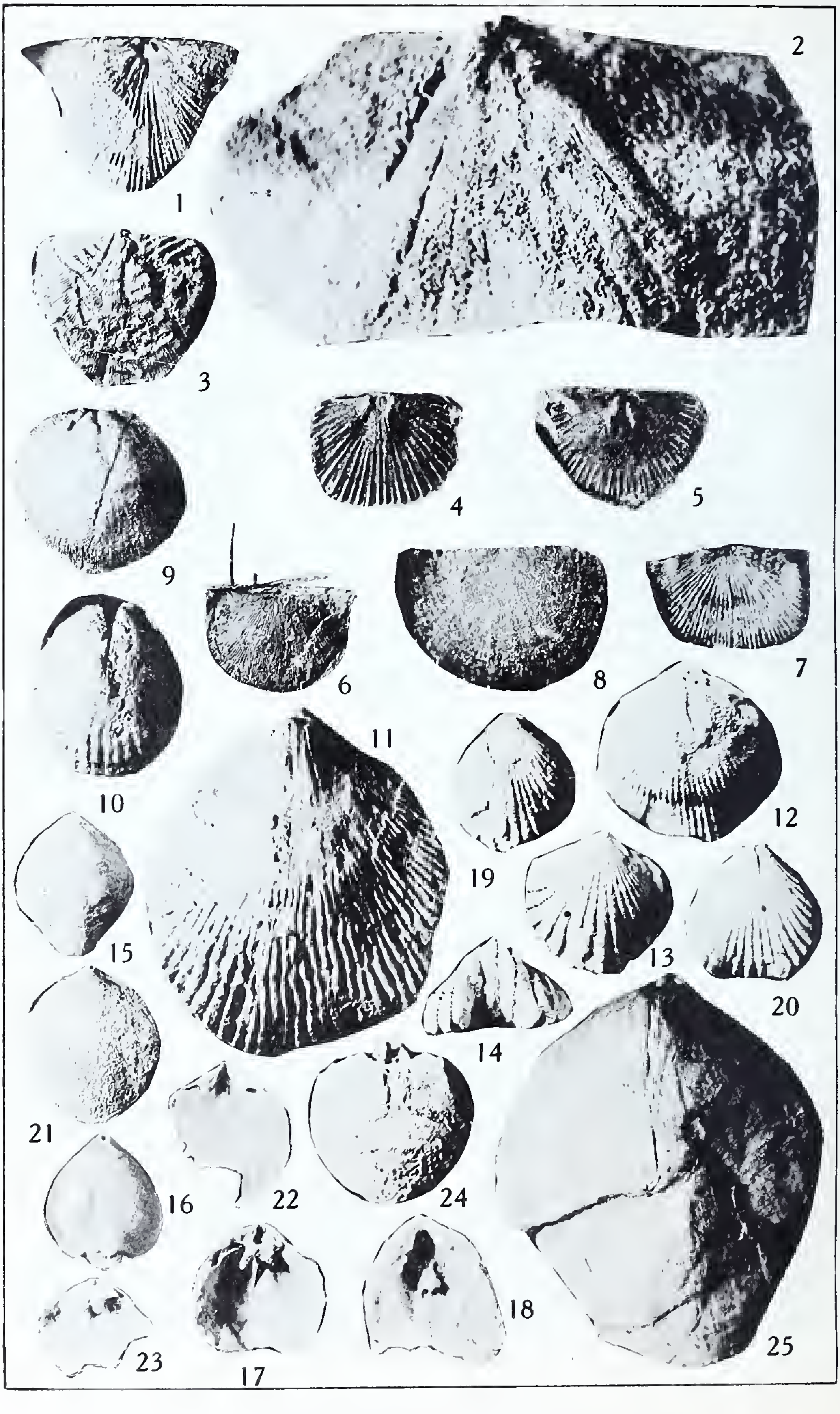
ORISKANY BRACHIOPODA



ORISKANY BRACHIOPODA

PLATE 12

Oriskany

BRACHIOPODA (Continued)

1. *Strophonella punctulifera* (Conrad), dorsal valve x 1, note punctae, Shriver, Snyder County.
2. *Stropheodonta magnifica* (Hall), ventral valve, interior x ⅔, Ridgeley, Bedford County.
3. *S. beckii* (Hall), ventral valve x 2/3, Ridgeley, Perry County.
4. *Schuchertella becraftensis* (Clarke), ventral valve x 2, Shriver, Huntingdon County.
5. *S. becraftensis* (Clarke), dorsal valve x 2, Shriver, Huntingdon County.
6. *Chonetes hudsonicus* Clarke, ventral valve x 1, Shriver, Blair County.
7. *C. hudsonicus* Clarke, ventral valve x 2, Shriver, Clinton County.
8. *Chonostrophia complanata* (Hall), ventral valve x 1¼, Ridgeley, Franklin County.
9. *Hipparionyx proximus* Vanuxem, dorsal valve x ⅔, Ridgeley, Lycoming County.
10. *Plethorhyncha speciosa* (Hall), ventral valve, internal cast x ¾, Ridgeley, Mifflin County.
11. *Straclenia barrandii* (Hall), ventral valve, internal cast x ¾, Ridgeley, Juniata County.
12. *S. pleiopleura* (Conrad), ventral valve internal cast x 1, Ridgeley, Perry County.
13. *Eatonia medialis* (Vanuxem), dorsal valve x ¾, Ridgeley, Perry County.
14. *E. medialis* (Vanuxem), anterior aspect x ¾, Ridgeley, Perry County.
15. *E. peculiaris* (Conrad), dorsal valve x 1½, Ridgeley, Perry County.
16. *E. peculiaris* (Conrad), dorsal valve x 1¼, Ridgeley, Bedford County.
17. *E. peculiaris* (Conrad), dorsal valve, interior x 1½, Ridgeley, Bedford County.
18. *E. peculiaris* (Conrad), ventral valve, interior x 1½, Ridgeley, Bedford County.
19. *Uncinulus vellicatus* (Hall), dorsal valve x 1, Shriver, Juniata County.
20. *U. vellicatus* (Hall), ventral valve x 1, Shriver, Juniata County.
21. *Rensselaeria suessana* (Hall), dorsal valve x ⅔, Ridgeley, Bedford County.
22. *R. suessana* (Hall), ventral valve, interior x 1, Ridgeley, Bedford County.
23. *R. suessana* (Hall), dorsal valve, interior x ¾, Ridgeley, Bedford County.
24. *R. (Beachia) ovalis* (Hall), dorsal valve, interior cast x ¾, Ridgeley, Bedford County.
25. "*Megalanteris*" *ovalis* Hall, dorsal valve x 1½, Ridgeley, Perry County.

PLATE 13

Oriskany

BRACHIOPODA, PELECYPODA AND GASTROPODA

BRACHIOPODA (Continued)

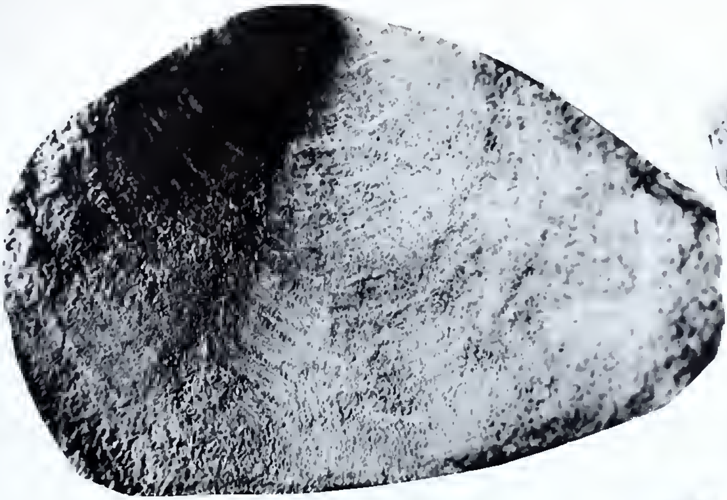
1. *Anoplotheca concava* (Hall), ventral valve, interior x 2, Ridgeley, Perry County..
2. *Meristella* sp. ind. (cf. "*gigantea*"), dorsal valve x 1, Ridgeley, Franklin County.
3. *M.* sp. ind., (cf. "*gigantea*"), dorsal valve x 1, Ridgeley, Franklin County.
4. *M. lentiformis* Clarke, dorsal valve x 1½, Shriver, Juniata County.
5. *M. lata* (Hall), dorsal valve x 1, Ridgeley, Bedford County.
6. *M. lata* (Hall), ventral valve x 1, Ridgeley, Bedford County.

PELECYPODA

7. *Actinopteria textilis* var. *arenaria* (Hall), left valve x ½, Ridgeley, Perry County.
8. *A. textilis* (Hall), left valve fragment x 1, Shriver, Blair County.

GASTROPODA

9. *Tentaculites reedsi* Vokes, x 1, Shriver, Blair County.
10. *Conularia pyramidalis* Hall, x 1, Shriver, Huntingdon County.
11. *C. pyramidalis* Hall, x 1, Shriver, Huntingdon County.
12. *Orthonychia tortuosum* (Hall), x 1, Ridgeley, Lycoming County.
13. *Platyceras nodosum* Conrad, x ⅔, Ridgeley, Juniata County.
14. *P. newberryi* Hall, x ¾, Shriver, Snyder County.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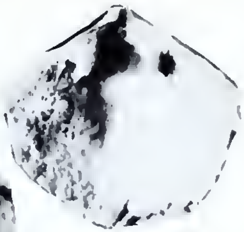
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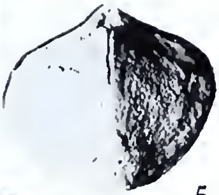
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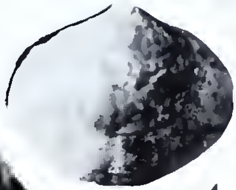
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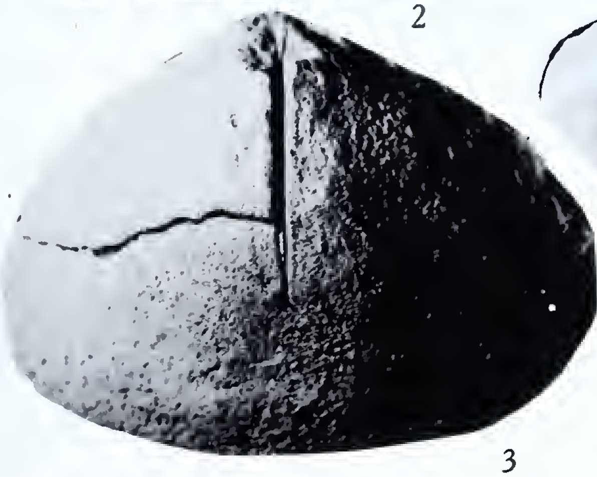
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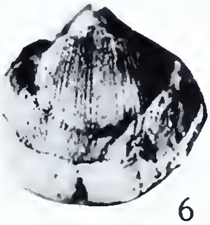
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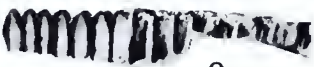
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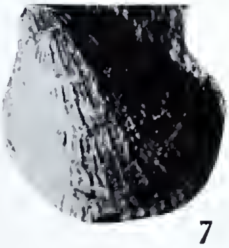
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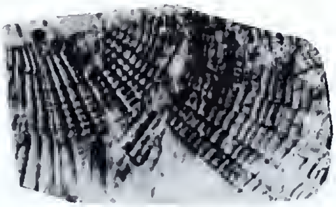
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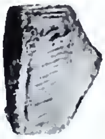
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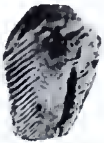
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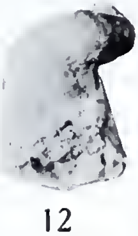
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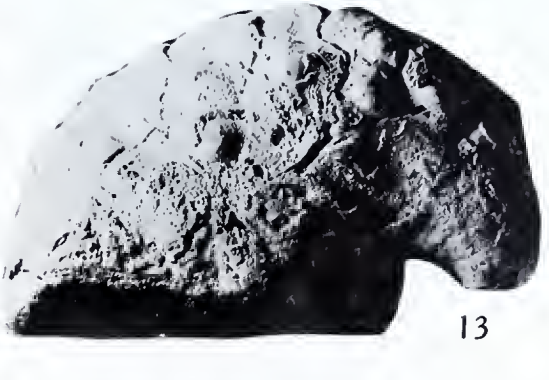
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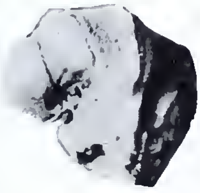
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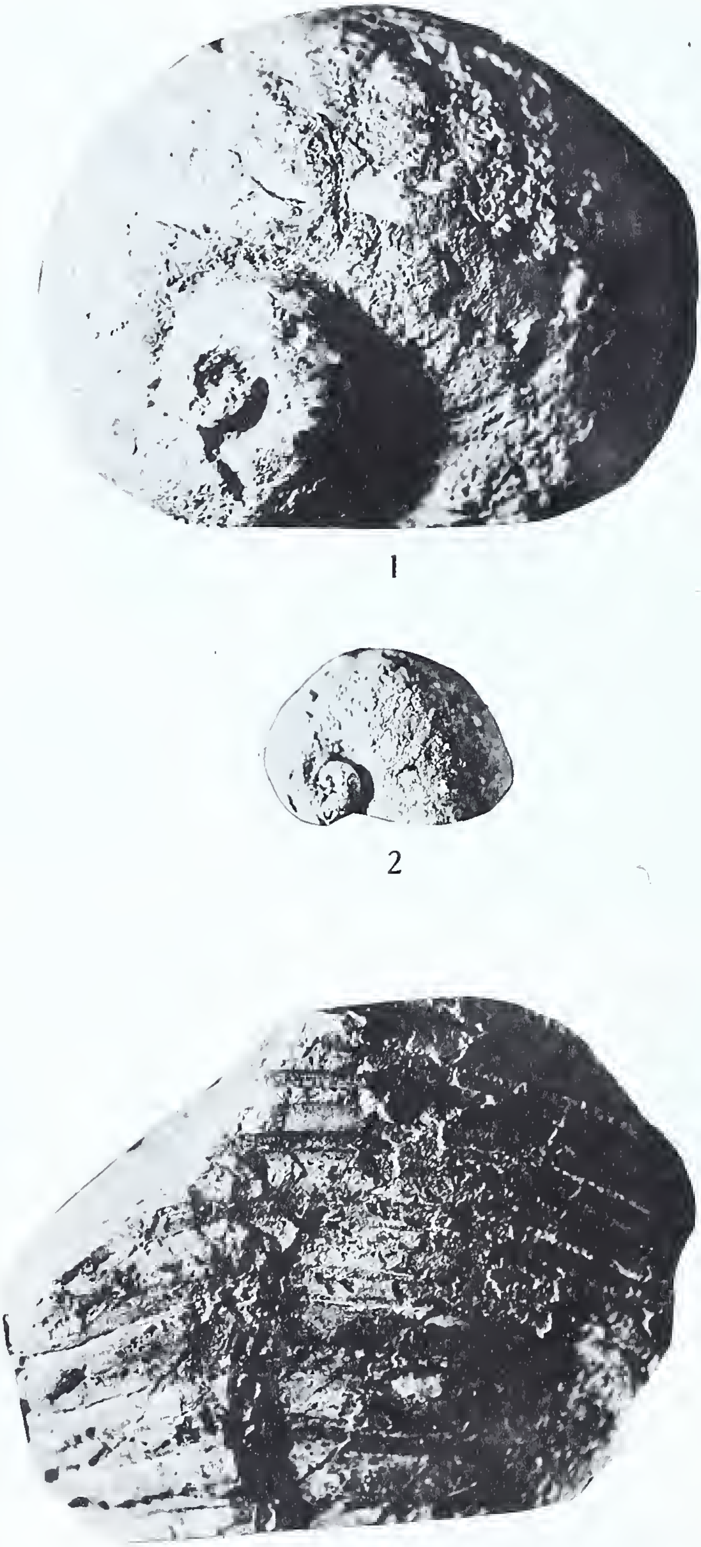
ORISKANY BRACHIOPODA, PELECYPODA, GASTROPODA



ORISKANY GASTROPODA AND TRILOBITE

PLATE 14

Oriskany

GASTROPODA AND TRILOBITE

GASTROPODA

1. *Diaphorostoma ventricosum* (Conrad), x 1, Ridgeley formation, Perry County.
2. *Platyceras gebhardi* Conrad, x ½, Ridgeley formation, Bedford County.

TRILOBITE

3. *Homalonotus* sp. ind., x 1, Ridgeley formation, Perry County.

PLATE 15

Middle and Upper Devonian

PORIFERA, COELENTERATA, "VERMES"

PORIFERA

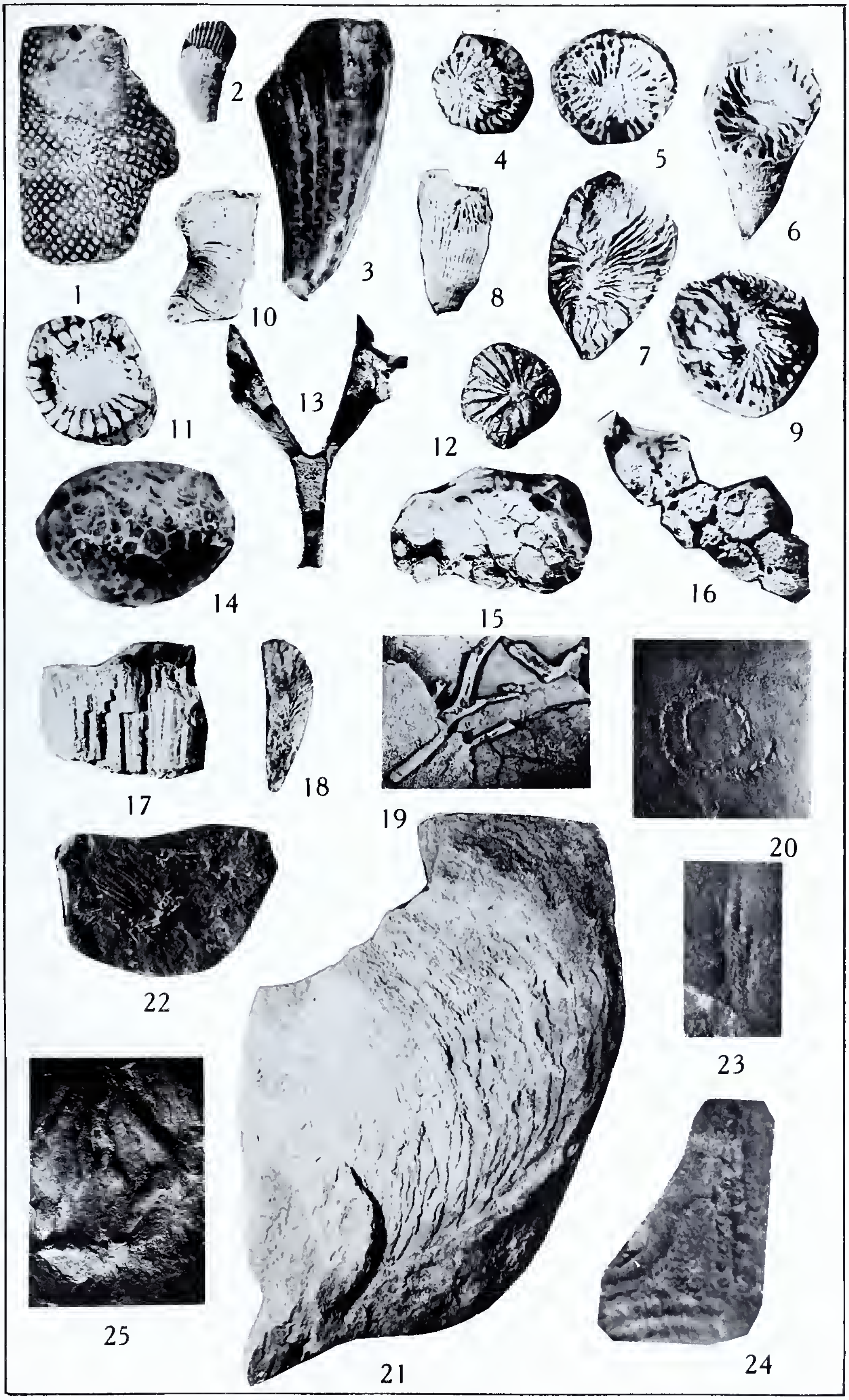
1. *Receptaculites* sp. x 1, Centerfield coral reef north of Stroudsburg, Monroe County.

COELENTERATA

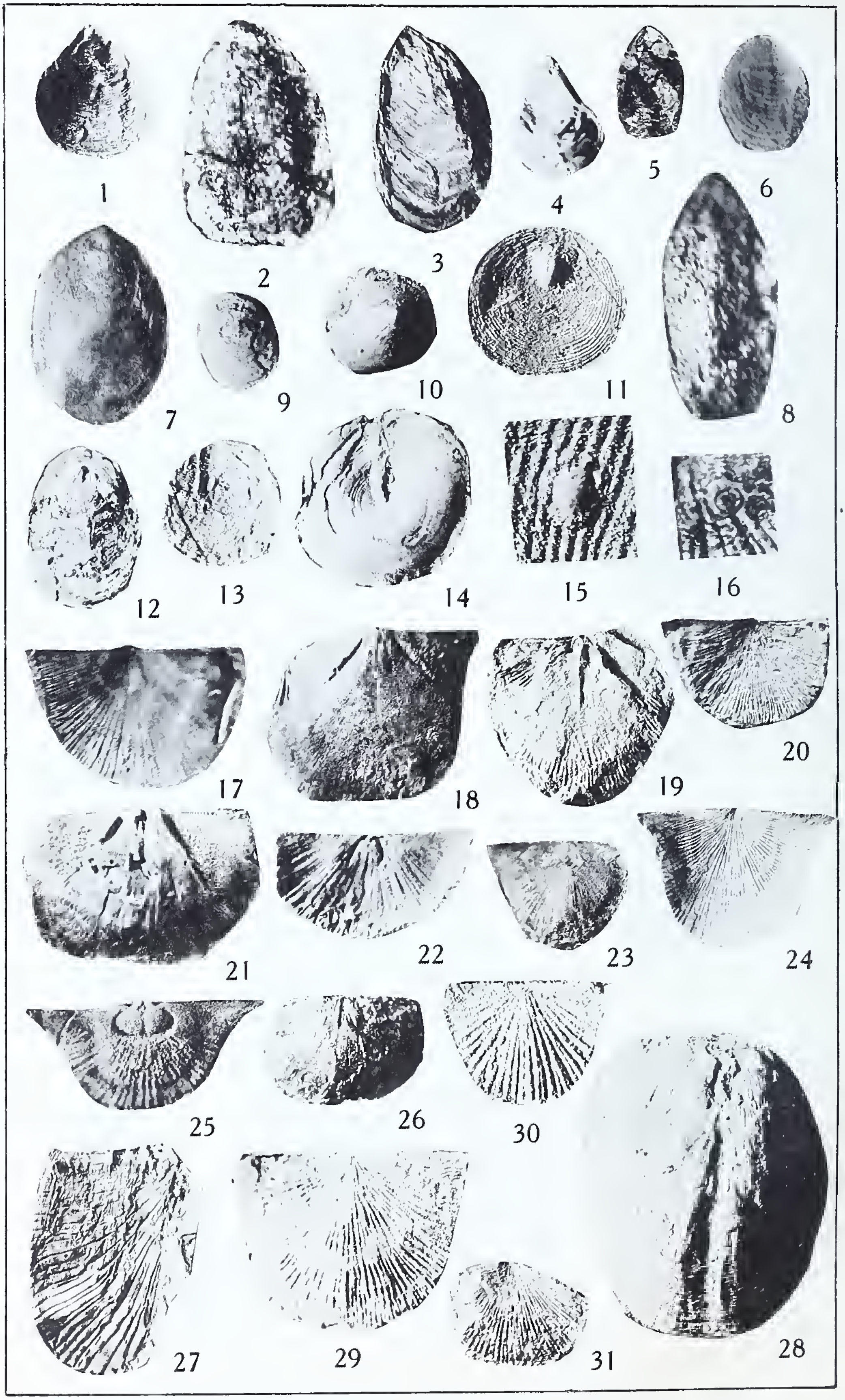
2. *Lopholasma tullium* J. S. Williams, x 1, top of Tully limestone, Larrys Creek, Lycoming County. (Photograph by G. A. Cooper.)
3. *L. tullium* J. S. Williams, oblique section x 2, top of Tully limestone, Larrys Creek, Lycoming County. (Photograph by G. A. Cooper.)
4. *Streptelasma rectum* (Hall), x 1, Centerfield coral reef north of Stroudsburg, Monroe County.
5. *S. rectum* (Hall), x 1½, Centerfield coral reef north of Stroudsburg, Monroe County.
6. *Zaphrentis prolifica* Billings, x 1, Selinsgrove limestone, Pine Creek, Lycoming County.
7. *Z. prolifica* Billings, x 1, Centerfield coral reef north of Stroudsburg, Monroe County.
8. *Z. simplex* Hall, x 1, Selinsgrove limestone, north of Beach Haven, Luzerne County.
9. *Z. simplex* Hall, x ½, Mahantango formation, Beach Haven, Luzerne County.
10. *Amplexus hamiltoniae* Hall, x 1, Selinsgrove limestone, Pine Creek, Lycoming County.
11. *A. hamiltoniae* Hall, x 1½, Mahantango formation, McMichaels Creek Valley north of Naola, Monroe County.
12. *Cyathophyllum* cf. *conatum* Hall, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
13. *Ceratopora jacksoni* Grabau, x 1, Mahantango formation, Huntingdon, Huntingdon County.
14. *Pleurodictyum stylopora* (Eaton), x 1, Mahantango formation, north of Mausdale, Montour County.
15. *P.* sp. x 1, Mahantango formation, north of Mausdale, Montour County.
16. *P.* sp. x 2, Mahantango formation, north of Mausdale, Montour County.
17. *Favosites hamiltoniae* Hall, x 1, Centerfield coral reef, north of Stroudsburg, Monroe County.
18. *F. limitaris* Rominger, x 1½, Hazard paint ore, Palmerton, Carbon County.
19. *Cladopora humilis* Clarke and Swartz, x 2, attached to *Elytha laevis,* Losh Run shale, 3 miles west of Chulasky, Northumberland County.

"VERMES"

20. Annelid trail (?), x ½, Catskill red beds, probably Damascus, Susquehanna County.
21. *Taonurus* sp. x ½, Mahantango formation, Board Run, Perry County.
22. *Pteridichnites biseriatus* Clarke and Swartz, x ½ Brallier shale, Cove Creek Valley, Fulton County.
23. *P. biseriatus* Clarke and Swartz, x 1, Brallier shale, Cove Creek Valley, Fulton County.
24. *P. biseriatus* Clarke and Swartz, x 1, Brallier shale, Shade Valley, Huntingdon County.
25. *Fucoides graphica* Hall, x ½, Brallier shale, Loyalsock Valley, Lycoming County.



MIDDLE AND UPPER DEVONIAN PORIFERA, COELENTERATA AND "VERMES"



MIDDLE AND UPPER DEVONIAN BRACHIOPODA

PLATE 16

Middle and Upper Devonian

BRACHIOPODA

1. *Linguella paliformis* Hall, ventral valve x 1, Mahantango formation bluffs north of Matamoras, Pike County.

2. *Lingula cuyahoga* Hall, ventral valve? x 2, Canadaway, Mill Creek, Tioga County.

3. *L. cuyahoga* Hall, ventral valve? x 2, Needmore shale, Aughwick Creek Valley, Fulton County.

4. *L. delia?* Hall, dorsal valve? x 2, Marcellus shale, quarry at Stroudsburg, Monroe County.

5. *L. ligea* Hall, dorsal valve? x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

6. *L. ligea* (?) Hall, dorsal valve? x 4, Mahantango formation, Dimmsville, Juniata County.

7. *L. oherni* Clarke and Swartz, ventral valve x 2, lower Portage shale, north side Little Mountain, Dauphin County.

8. *L. spatulata* (?) Vanuxem, ventral valve? x 6, Canadaway, Mill Creek, Tioga County.

9. *Orbiculoidea neglecta* (Hall), dorsal valve x 6, lower Portage shale, Pennsylvania R. R. north of Northumberland, Northumberland County.

10. *O. lodiensis* var. *media* Hall, dorsal valve x 3, Onondaga black shale, Schellsburg, Bedford County.

11. *O. lodiensis* var. *media* Hall, ventral valve x 2, Onondaga black shale, Bedford County.

12. *O. alleghania* (Hall), dorsal valve x ¾, Franklindale limestone, 2.5 miles east of Franklindale, Bradford County.

13. *O. minuta* (Hall), dorsal valve x 4, Marcellus formation, Pennsylvania R. R. east of Schuylkill Haven, Schuylkill County.

14. *Roemerella grandis* (Vanuxem), ventral valve x ¾, Mahantango formation, bluffs north of Matamoras, Pike County.

15. *Craniella?* x 4, attached to *Paleoneila fecunda*, Mahantango formation, Eichelbergertown, Bedford County.

16. *Craniella?* x 4, attached to fragment of *Stropheodonta* sp. Hazard paint ore, Palmerton, Carbon County.

17. *Leptostrophia interstrialis* (Vanuxem), ventral valve x 1, Chemung Blues Gap, Bedford County.

18. *L. perplana* (Conrad), ventral valve, internal cast x 1, Mahantango formation, Cove Creek, Fulton County.

19. *L. perplana* (Conrad), ventral valve, internal cast x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

20. *L. perplana* var. *nervosa* Hall, dorsal valve, exterior x 1, Chemung, 8 miles south of Sayre, Bradford County.

21. *L. perplana* var. *nervosa* Hall, ventral valve, interior x ¾, Canadaway, Smith Creek Valley, Tioga County.

22. *L. perplana* var. *alternata* Clarke and Swartz, ventral valve, internal cast x 1, Chemung, north bank Cowanesque River, Tioga County.

23. *Douvillina arcuata* (Hall), ventral valve. exterior x 2, "Chemung," north bank Cowanesque River, Tioga County.

24. *D. cayuta* (Hall), ventral valve, exterior x 1, "Chemung," Elkhorn Creek Valley, Tioga County.

25. *D. cayuta* (Hall), ventral valve, internal cast x 1, "Chemung," 50-foot cliff on Elkhorn Creek, Tioga County.

26. *D. cayuta* var. *graciliora* (?) Clarke and Swartz, Chemung coquinite zone O, section north of Lock Haven along Susquehanna River, Clinton County.

27. *Stropheodonta concava* Hall, dorsal valve, exterior x 1, Moscow shale, Barnetts Mill, Perry County.

28. *S. concava* Hall, ventral valve, internal cast x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

29. *S. demissa* (Conrad), ventral valve, exterior x 1, Trimmers Rock sandstone, Meiserville, Snyder County.

30. *S. demissa* (Conrad), ventral valve, exterior x 2, Trimmers Rock sandstone, Meiserville, Snyder County.

31. *S. demissa* (Conrad), ventral valve, exterior x 2, Trimmers Rock sandstone, Meiserville, Snyder County.

PLATE 17

Middle and Upper Devonian

BRACHIOPODA

1. *Stropheodonta demissa* (Conrad), ventral valve, exterior x 2, Mahantango formation, Brodhead Creek Valley, Monroe County.
2. *S. inequistriata* (Conrad), ventral valve, exterior x 2, Mahantango formation, Pennsylvania R. R. east from Bloomsburg, Columbia County.
3. *S. inequistriata* (Conrad), ventral valve, exterior x 1, Lehigh Valley paint ore, Palmerton, Carbon County.
4. *S. maynardi* Clarke and Swartz, dorsal valve, exterior x 1, Chemung, coquinite zone O, Susquehanna Valley north of Lock Haven, Clinton County.
5. *S. patersoni* Hall, ventral valve, exterior x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
6. *S. patersoni* Hall, ventral valve, exterior x 1, Hazard paint ore, Palmerton, Carbon County.
7. *Pholidostrophia pennsylvanica* Kindle, ventral valve, exterior x 4, Needmore shale, Susquehanna River & Western R. R. southeast of New Bloomfield, Perry County.
8. *Leptaena rhomboidalis* (Wilckens), dorsal valve. exterior x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
9. *L. rhomboidalis* (Wilckens), dorsal valve, exterior x 1, Onondaga, Bowmans, Carbon County.
10. *Schuchertella chemungensis* (Conrad), ventral valve, internal east x ½, "Chemung," north of Gaines, Tioga County.
11. *S. chemungensis* (Conrad), dorsal valve, internal cast x ½, "Chemung," 1.5 miles west of Jackson Summit, Tioga County.
12. *S. elliptica* Clarke and Swartz, ventral valve, interior x 1, "Chemung," Lehigh Valley R. R. south of Homets Ferry, Bradford County.
13. *S. pandora* (Billings), ventral valve, exterior x 1 Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
14. *S. pandora* (Billings), ventral valve, exterior x 1, Hazard paint ore, Palmerton, Carbon County.
15. *S. variabilis* Prosser, dorsal valve, exterior x 1, Montebello sandstone, north of Sterretts Gap, Perry County.
16. *S. variabilis* Prosser, dorsal valve, exterior x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
17. *Chonetes aurora* (Hall), ventral valve, exterior x 6, massive Tully limestone, Bedford County. (Photograph by G. A. Cooper.)
18. *C. aurora* (Hall), ventral valve, interior x 3, massive Tully limestone, Blair County. (Photograph by G. A. Cooper.)
19. *Eodevonaria arcuata* Hall, ventral valve, exterior. x 1, Hazard paint ore, Palmerton Carbon County. (Photograph by L. Whitcomb.)
20. *E. arcuata* (Hall), ventral valve, interior, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
21. *E. arcuata* (Hall), ventral valve, interior x 1½, Needmore shale, Mahantango Creek Valley, Snyder County.

22. *E. arcuata* (?) (Hall), dorsal valve, exterior x 2, Needmore shale, Mahantango Creek Valley, Snyder County.

23. *E. arcuata* (Hall), ventral valve, interior x 2, Needmore shale, Mahantango Creek Valley, Snyder County.

24. *Chonetes buttsi* Kindle, ventral valve, exterior x 2, Onondaga black shale, Pennsylvania R. R. at Newton Hamilton, Mifflin County.

25. *C. buttsi* Kindle, ventral valve, exterior x 1, Onondaga black shale, Pennsylvania R. R. at Newton Hamilton, Mifflin County.

26. *C. buttsi* Kindle, dorsal valve, exterior x 1, Onondaga black shale, Pennsylvania R. R. at Newton Hamilton, Mifflin County.

27. *C. coronatus* (Conrad), ventral valve, interior x ½, Mahantango formation (middle sandstone), Chaneysville, Bedford County.

28. *C. hemisphericus* (Hall), ventral valve, interior x 2, Selinsgrove limestone, Pennsylvania R. R. at Newton Hamilton, Mifflin County.

29. *C. lepidiformis* Clarke and Swartz, ventral valve, interior x 3, Trimmers Rock sandstone, Juniata Valley, east side, Perry County.

30. *C. lepidus* Hall, ventral valve, internal east x 3, Mahantango formation, Eichelbergertown, Bedford County.

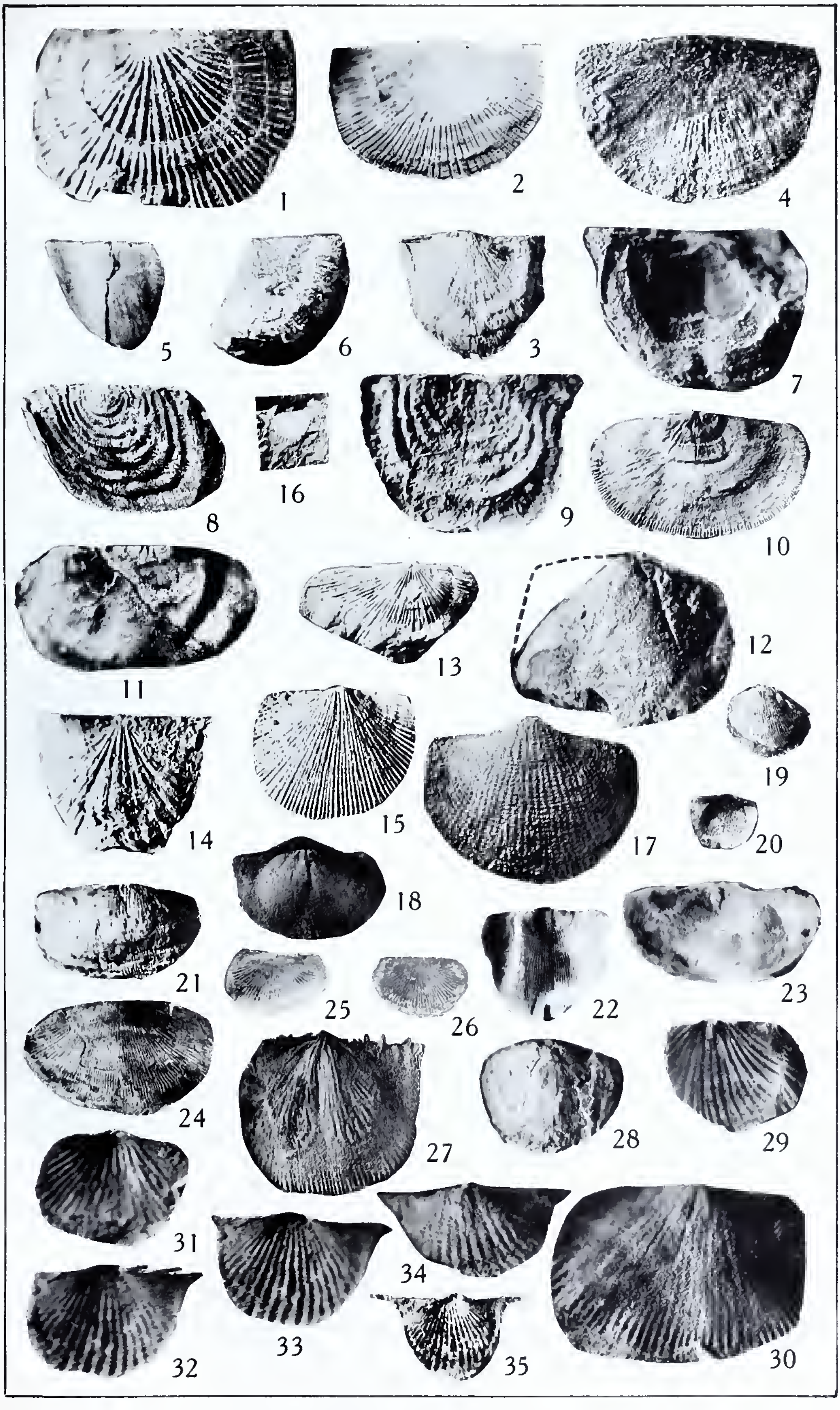
31. *C. lepidus*, ventral valve, interior x 1, Mahantango formation, Aughwick Creek Valley, Fulton County.

32. *C. mucronatus* Hall, ventral valve x 2, Marcellus shale, Stroudsburg quarry, Monroe County.

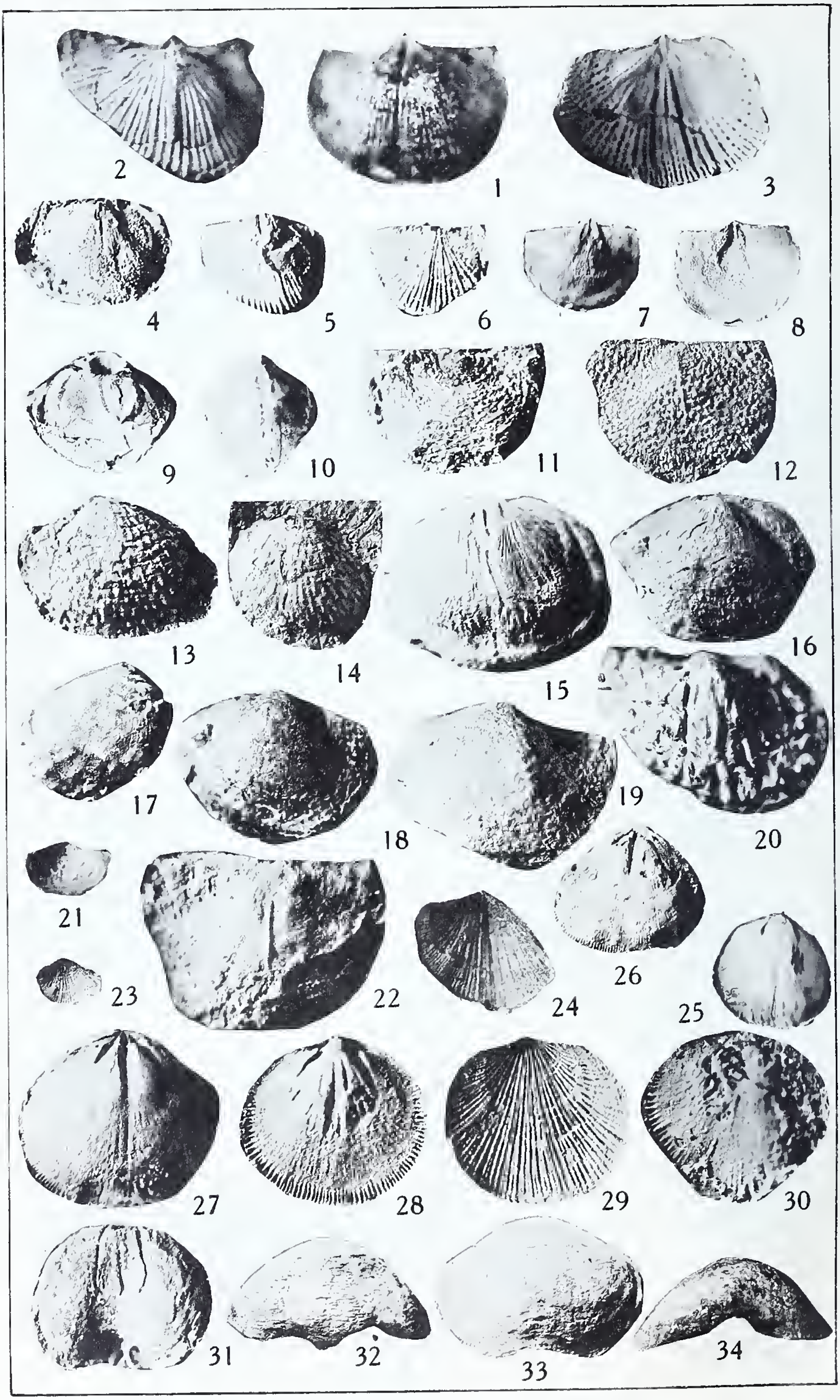
33. *C. mucronatus* Hall, ventral valve x 2, Marcellus shale, Stroudsburg quarry, Monroe County.

34. *C. mucronatus* Hall, ventral valve x 2, Marcellus shale, Stroudsburg quarry, Monroe County.

35. *C. mucronatus* Hall, ventral valve, exterior x 2, Mahantango formation, Needmore, Fulton County.



MIDDLE AND UPPER DEVONIAN BRACHIOPODA



MIDDLE AND UPPER DEVONIAN BRACHIOPODA

PLATE 18

Middle and Upper Devonian

BRACHIOPODA

1. *Chonetes scitulus* Hall, ventral valve, internal cast x 1½, Mahantango formation, Reading R. R. north of Auburn, Schuylkill County.
2. *C. vicinus* (Castelnau), ventral valve, exterior x 2, locality unknown.
3. *C. vicinus* (Castelnau), ventral valve, interior x 2, Mahantango formation, Dimmsvile, Juniata County.
4. *C. setiger* (Hall), ventral valve, internal cast x 2, Mahantango formation, Lehigh River Valley, Carbon County.
5. *C. setiger* (Hall), ventral valve, exterior x 2, Mahantango formation, Lehigh River Valley, Carbon County.
6. *C. setiger* (Hall) dorsal valve, exterior x 2, Mahantango formation, Lehigh River Valley, Carbon County.
7. *Anoplia nucleata* Hall, ventral valve, internal cast x 2, Selinsgrove limestone, Swatara Gap, Lebanon County.
8. *A. nucleata* Hall, ventral valve, exterior cast x 2, Selinsgrove limestone, Swatara Gap, Lebanon County.
9. *Strophalosia truncata* (Hall), crushed ventral valve, internal cast x 2, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
10. *S. truncata* (Hall), ventral valve, exterior x 2, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
11. *Productella arctirostrata* Hall, dorsal valve, exterior x 1, "Chemung," Pine Creek, Lycoming County.
12. *P. lachrymosa* (Conrad), dorsal valve, exterior x 1, "Chemung," Bear Creek, Tioga County.
13. *P. lachrymosa* (Conrad), ventral valve, exterior x 1, "Chemung," Bear Creek, Tioga County.
14. *P. lachrymosa* (Conrad), ventral valve, exterior showing spines, x 1, Chemung, Fyan Mill, Bedford County.
15. *P. lachrymosa* var. *stigmata* Hall, ventral valve, internal cast x ½, Canadaway, Luthers Mills, Bradford County.
16. *P. lachrymosa* var. *stigmata* Hall, ventral valve, internal cast x ½, Canadaway, south of Hallenback, Bradford County.
17. *P. lachrymosa* var. *lima* (?) (Conrad), ventral valve, exterior x ⅔, Chemung, Franklindale, Bradford County.
18. *P. onusta* Hall, ventral valve, exterior x 1, Canadaway, north branch Thornbottom Creek, Tioga County.
19. *P. speciosa* Hall, ventral valve, exterior x 1, Canadaway, north branch Thornbottom Creek, Tioga County.
20. *P. spinulicosta* Hall, ventral valve, exterior x 3, Mahantango formation, Harrisonville, Fulton County.
21. *P. hystricula* Hall, ventral valve, exterior x 4, Trimmers Rock sandstone, south of Little Wapwallopen Creek, Luzerne County.
22. *Productus hallanus* Walcott, dorsal valve, internal cast x 1, Trimmers Rock sandstone, Meiserville, Snyder County.

23. *Dalmanella lenticularis* (Vanuxem), ventral valve, exterior x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

24. *D. lenticularis* (Vanuxem), ventral valve, exterior x 2, Hazard paint ore, Palmerton, Carbon County.

25. *D. lenticularis* (Vanuxem), ventral valve, internal cast x 2, Mahantango formation, Dimmsville, Juniata County.

26. *Rhipidomella leucosia* Hall, dorsal valve, internal cast x 1, Mahantango formation, Richfield, Juniata County.

27. *R. leucosia* Hall, dorsal valve, internal cast x 1½, Mahantango formation, Richfield, Juniata County.

28. *R. penelope* Hall, ventral valve, internal cast x 1, Mahantango formation, Bedford, Bedford County.

29. *R. vanuxemi* Hall, dorsal valve, exterior x 2, Mahantango formation west of Newport, Perry County.

30. *R. vanuxemi* Hall, ventral valve, internal cast x 2, Mahantango formation, Oak Run, Lycoming County.

31. *Schizophoria striatula* (Schlotheim), ventral valve, internal cast x ¾, "Chemung", north of Gaines, Tioga County.

32. *S. striatula* (Schlotheim), ventral valve, posterior aspect x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

33. *S. striatula* (Schlotheim), ventral valve, exterior, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

34. *S. striatula* (Schlotheim), ventral valve, anterior aspect x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

PLATE 19

Middle and Upper Devonian

BRACHIOPODA

1. *Schizophoria propinqua* Hall, dorsal valve, exterior, x 1, Hazard paint ore, Palmerton, Carbon County.
2. *Pentamarella arata* (Conrad), ventral valve, exterior, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
3. *P. arata* (Conrad), ventral valve, lateral aspect, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
4. *P. arata* (Conrad), ventral valve, exterior, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
5. *P.* sp., ventral valve, exterior, fragmentary, x 1, Tully shale, Imler, Bedford County. (Photograph by G. A. Cooper.)
6. *Camarotœchia congregata* (Conrad), dorsal valve, internal cast x ¾, "Chemung" north of Stokesdale, Tioga County.
7. *C. congregata* (Conrad), dorsal valve, internal cast x ¾, "Chemung" north of Stokesdale, Tioga County.
8. *C. congregata* var. *parkheadensis* Clarke and Swartz, dorsal valve, exterior, x ½, Chemung on R. R. north of Cypher, Bedford County.
9. *C. congregata* var. *parkheadensis* Clarke and Swartz, dorsal valve, exterior, x ½, "Chemung" east of Uniontown, Fayette County.
10. *C. contracta* (Hall), ventral valve, exterior, x 1½, Chemung, Manns Choice, Bedford County.
11. *C. dotis* Hall, ventral valve, exterior, x 1, Marcellus shale, Pennsylvania R. R. east of Schuylkill Haven, Schuylkill County.
12. *C. eximia* Hall, ventral valve, internal cast, x 1, Chemung?, Everett, Bedford County.
13. *C. eximia* Hall, dorsal valve, internal cast, x 2, Chemung, Susquehanna River Valley north of Lock Haven, Clinton County.
14. *C. eximia* Hall, ventral valve, internal cast, x 2, Chemung, Susquehanna River Valley north of Lock Haven, Clinton County.
15. *C. horsfordi* Hall, ventral valve, internal cast (crushed), x 2, "Chemung," north branch Thornbottom Creek, Tioga County.
16. *C. horsfordi* Hall, dorsal valve, internal cast, x 1 "Chemung" east of Uniontown, Fayette County.
17. *C. orbicularis* Hall, dorsal valve, internal cast, x 1, "Chemung" east of Uniontown, Fayette County.
18. *C. orbicularis* Hall, dorsal valve, internal cast, x 1, "Chemung" east of Uniontown, Fayette County.
19. *C. orbicularis* Hall, dorsal valve, lateral aspect, x 1, "Chemung" iron ore 3.8 miles east of Wellsboro, Tioga County.
20. *C. prolifica* Hall, dorsal valve, internal cast x 2, Mahantango formation south of Juniata River at Huntingdon, Huntingdon County.
21. *C. stevensi* (?) Hall, ventral valve, internal cast x 2, Chemung, Franklindale, Bradford County.
22. *C. sappo* Hall, ventral valve, internal cast x 1½, New Milford formation, north of Lemon, Wyoming County.

23. *C. sappo* Hall, dorsal valve, internal cast x 1½, New Milford formation, north of Lemon, Wyoming County.

24. *C. sappo* Hall, dorsal valve, internal cast x 1, New Milford formation, north of Lemon, Wyoming County.

25. *Liorhynchus globuliforme* (Vanuxem), dorsal valve, internal cast x 1, Trimmers Rock sandstone, Big Fishing Creek Valley north of Light Street, Columbia County.

26. *L. laura* (Billings), dorsal valve x 1, Mahantango formation, Dimmsville, Juniata County.

27. *L. laura* (Billings), dorsal valve, exterior x 1, Mahantango formation, Dimmsville, Juniata County.

28. *L. limitare* (Vanuxem), dorsal valve, internal cast x 1, Marcellus shale, Huntingdon, Huntingdon County.

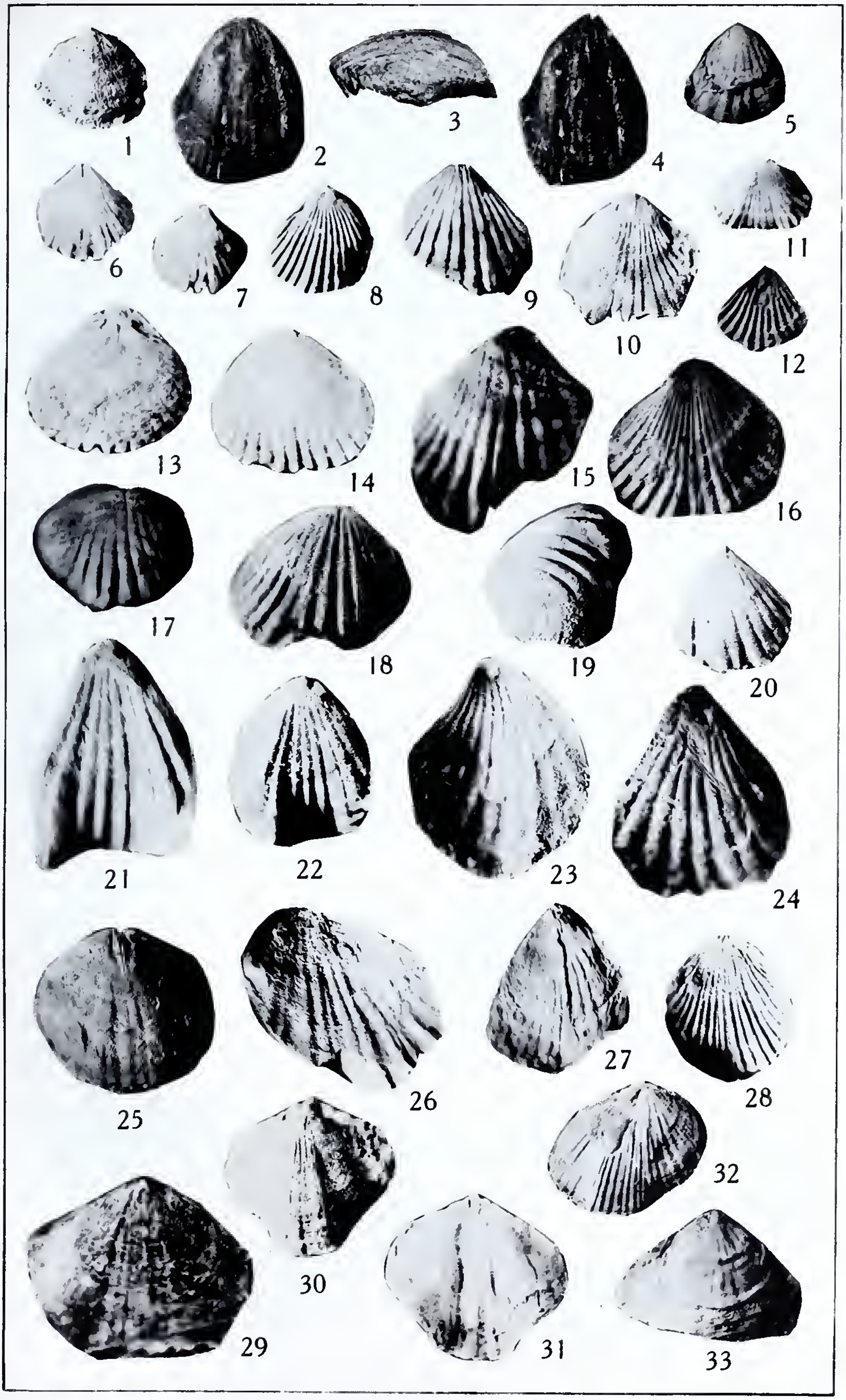
29. *L. mesacostale* Hall, ventral valve, internal cast x 1, Chemung, Manns Choice, Bedford County.

30. *L. mesacostale* Hall, dorsal valve, internal cast x ¾, Chemung, Manns Choice, Bedford County.

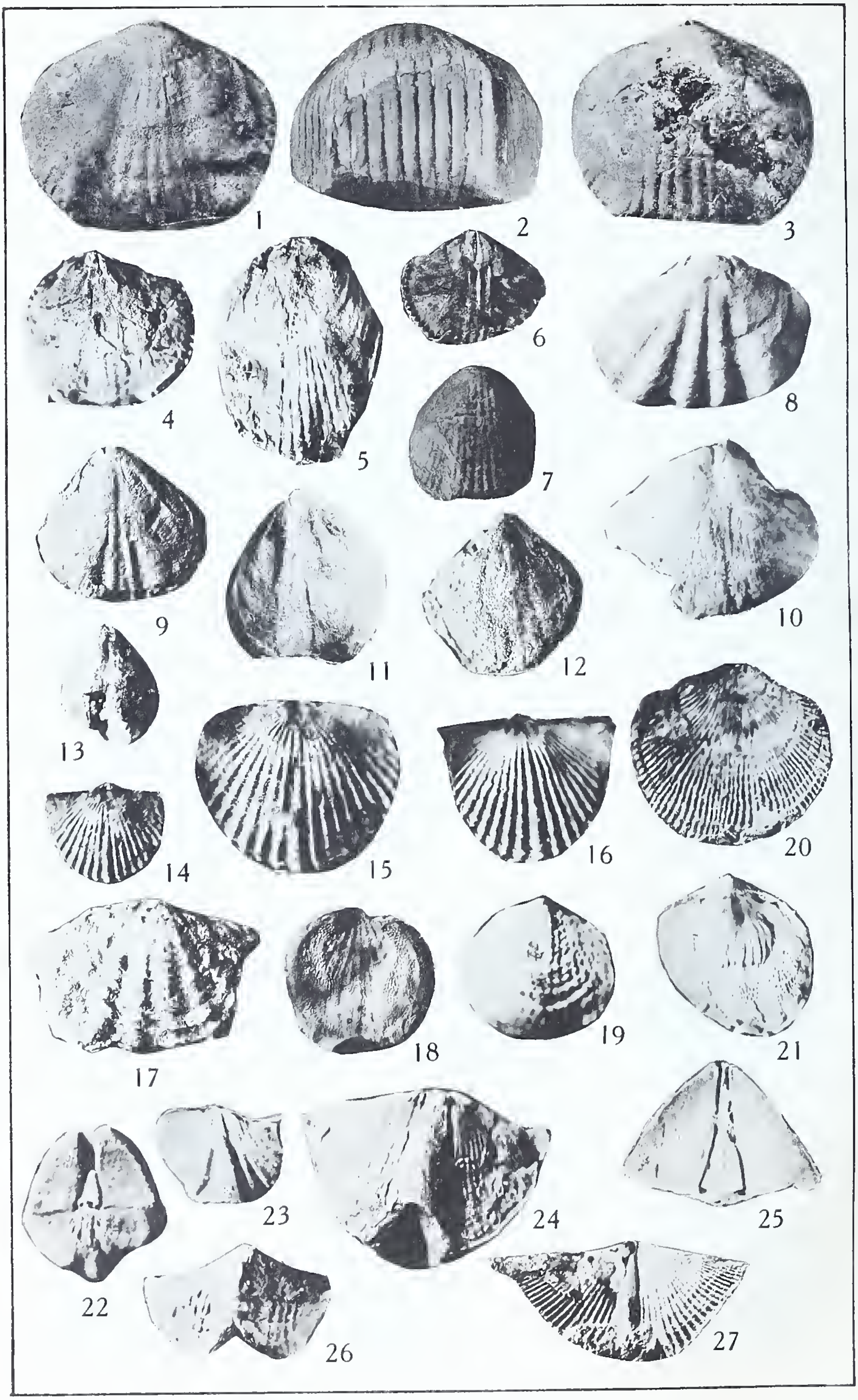
31. *L. mesacostale* Hall, ventral valve, internal cast x ¾, Losh Run shale?, 6.1 miles east of Northumberland, Northumberland County.

32. *L. multicostum* Hall, dorsal valve, internal cast x 1, "Chemung," north branch Thornbottom Creek, Tioga County.

33. *L. quadricostatum* (Vanuxem), dorsal valve, internal cast x 1, Mahantango formation, northwest of Landingsville, Schuylkill County.



MIDDLE AND UPPER DEVONIAN BRACHIOPODA



MIDDLE AND UPPER DEVONIAN BRACHIOPODA

PLATE 20

Middle and Upper Devonian

BRACHIOPODA

1. *Hypothyridina venustula* (Hall), ventral valve, exterior x 2, massive Tully limestone, south-central Pennsylvania. (Photograph by G. A. Cooper.)
2. *H. venustula* (Hall), anterior aspect x 2, massive Tully limestone, south-central Pennsylvania. (Photograph by G. A. Cooper.)
3. *H. venustula* (Hall), dorsal valve, exterior x 2, massive Tully limestone, south-central Pennsylvania. (Photograph by G. A. Cooper.)
4. *H. venustula* (Hall), ventral valve x 1, Laurens member, Monroe County.
5. *H. venustua* (Hall), dorsal valve, internal cast x 1, distorted specimen, Laurens member, Monroe County.
6. *H. venustula* (Hall), ventral valve, internal cast x 1, Laurens member, Monroe County. (Photograph by G. A. Cooper.)
7. *H. venustula* (Hall), dorsal valve, exterior x 1, Laurens member, Monroe County. (Photograph by G. A. Cooper.)
8. *Pugnax pugnus* (Martin), ventral valve, exterior x 2, Trimmers Rock sandstone, 6 miles east of Northumberland, Northumberland County.
9. *P. pugnus* var. *altus* (Calvin), ventral valve, exterior x 2, Portage, Newry, Blair County.
10. *Centronella ovata* Hall (?), dorsal valve, internal cast x 2, Mahantango formation, Chaneysville, Bedford County.
11. *Cryptonella eudora* Hall, ventral valve, internal cast x 1, "Chemung", New York State ½ mile north of Elkland, Tioga County, Pennsylvania.
12. *Newberria* sp. ventral valve, internal cast x ¾, Montbello sandstone, Rockville, Dauphin County.
13. *Eunella lincklœni* Hall, ventral valve, internal cast x 1½, Mahantango formation, Selinsgrove Junction, Northumberland County.
14. *Tropidoleptus carinatus* (Conrad), ventral valve, exterior x 1, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
15. *T. carinatus* (Conrad), ventral valve, exterior x 2, Mahantango formation, Board Run, Perry County.
16. *T. carinatus* (Conrad), ventral valve, exterior x 2, Mahantango formation, Board Run, Perry County.
17. *Atrypa hystrix* Hall, ventral valve, exterior x 1, "Chemung," Bear Creek Valley, Tioga County.
18. *A. hystrix* Hall, ventral valve, internal cast x ¾, Chemung, Deeters Gap, Somerset County.
19. *A. spinosa* Hall, dorsal valve, exterior x 1, massive Tully limestone, Curtin, Centre County.
20. *A. reticularis* (Linnæus), ventral valve, exterior x ¾, Trimmers Rock sandstone, Perry County.
21. *A. reticularis* (Linnæus), ventral valve, internal cast x 1, Mahantango formation west of Roseglen, Perry County.
22. *Cyrtina hamiltonensis* Hall, posterior aspect x 2, Trimmers Rock sandstone, Bartonville, Monroe County.
23. *C. hamiltonensis* Hall, dorsal valve, internal cast, x 2, Mahantango formation, Chaneysville, Bedford County.
24. *Cyrtia alta* Hall, ventral valve, internal cast x ½, post-Chemung, northeast of Corry, Erie County.
25. *C. alta* Hall, posterior aspect x ½, post-Chemung, north-east of Corry, Erie County.
26. "*Spirifer*" *acuminatus* (Conrad), anterior aspect x ½, Mahantango formation, Chaneysville, Bedford County.
27. "*S.*" *angustus* Hall, ventral valve x 1, Mahantango formation, Pennsylvania R. R. east of Bloomsburg, Columbia County.

PLATE 21

Middle and Upper Devonian

BRACHIOPODA

1. "*Spirifer*" *audaculus* (Conrad), dorsal valve, internal cast x ¾, Mahantango formation, Harrisonville, Fulton County.
2. "*S.*" *audaculus* (?) (Conrad), dorsal valve, internal cast x ¾, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
3. "*S.*" *audaculus* (Conrad), ventral valve, internal cast, Montebello sandstone, Half Falls Mountain, Perry County.
4. "*S.*" *consorbrinus* d'Orbigny, ventral valve ¾ Mahantango formation, Beach Haven, Luzerne County.
5. "*S.*" *disjunctus* Sowerby, dorsal valve, internal cast x ¾, Conewango, west of Corry, Erie County.
6. "*S.*" *disjunctus* Sowerby, ventral valve, internal cast x ¾, Conewango, west of Corry, Erie County.
7. "*S.*" *divaricatus*, ventral valve, internal cast x ½, Centerfield coral reef north of Stroudsburg, Monroe County.
8. "*S.*" *divaricatus*, dorsal valve, internal cast x ½, Centerfield coral reef north of Stroudsburg, Monroe County.
9. "*S.*" *granulosus* (Conrad), enlarged x 2 to show surface texture, Mahantango formation, Little Fishing Creek Valley, Columbia County.
10. "*S.*" *granulosus* (Conrad), dorsal valve, fragmentary, x ½, Mahantango formation, Little Fishing Creek Valley, Columbia County.
11. "*S.*" *granulosus* (Conrad), ventral valve x ½, Mahantango formation, Little Fishing Creek Valley, Columbia County.
12. "*S.*" *marcyi* var. *superstes* Clarke and Swartz, dorsal valve, internal cast x ½, Parkhead sandstone, Shy Beaver, Huntingdon County.
13. "*S.*" *mesacostalis* Hall, ventral valve, internal cast x 1, Trimmers Rock sandstone, Pine Creek Valley, Lycoming County.
14. "*S.*" *mesacostalis* Hall, ventral valve, internal cast x 1, Trimmers Rock sandstone, Pine Creek Valley, Lycoming County.
15. "*S.*" *mesastrialis* Hall, dorsal valve, exterior x ¾, Trimmers Rock sandstone, Newport, Perry County.
16. "*S.*" *mesastrialis* Hall, ventral valve, exterior x ¾, Trimmers Rock sandstone, Newport, Perry County.
17. "*S.*" *mucronatus* (Conrad), ventral valve, internal cast x 1, Mahantango formation, Reeds Gap, Juniata County.
18. "*S.*" *mucronatus* var. *posterus* Hall and Clarke, ventral valve, interior x 1, Trimmers Rock sandstone, Meiserville, Snyder County.
19. "*S.*" *mucronatus* var. *posterus* Hall and Clarke, ventral valve, internal cast x 2, Trimmers Rock sandstone, 2.8 miles north of Mausdale, Montour County.
20. "*S.*" *pauliformis* J. S. Williams, dorsal valve x 2, shaly Tully, South Danville, Northumberland County. (Photograph by G. A. Cooper.)
21. "*S.*" *pauliformis* J. S. Williams, dorsal valve, fragmentary, x 2, shaly Tully, South Danville, Northumberland County. (Photograph by G. A. Cooper.)

22. "*S.*" *raricostus* Hall, ventral valve, exterior x 1, Selinsgrove limestone, Mahantango Creek, Snyder County.

23. "*S.*" *sculptilis* Hall, ventral valve, interior x 1, Mahantango formation, Bedford, Bedford County.

24. "*S.*" *tullius* Hall, ventral valve, internal cast x ½, top Mahantango formation (Moscow), Lehigh River Valley, Carbon County.

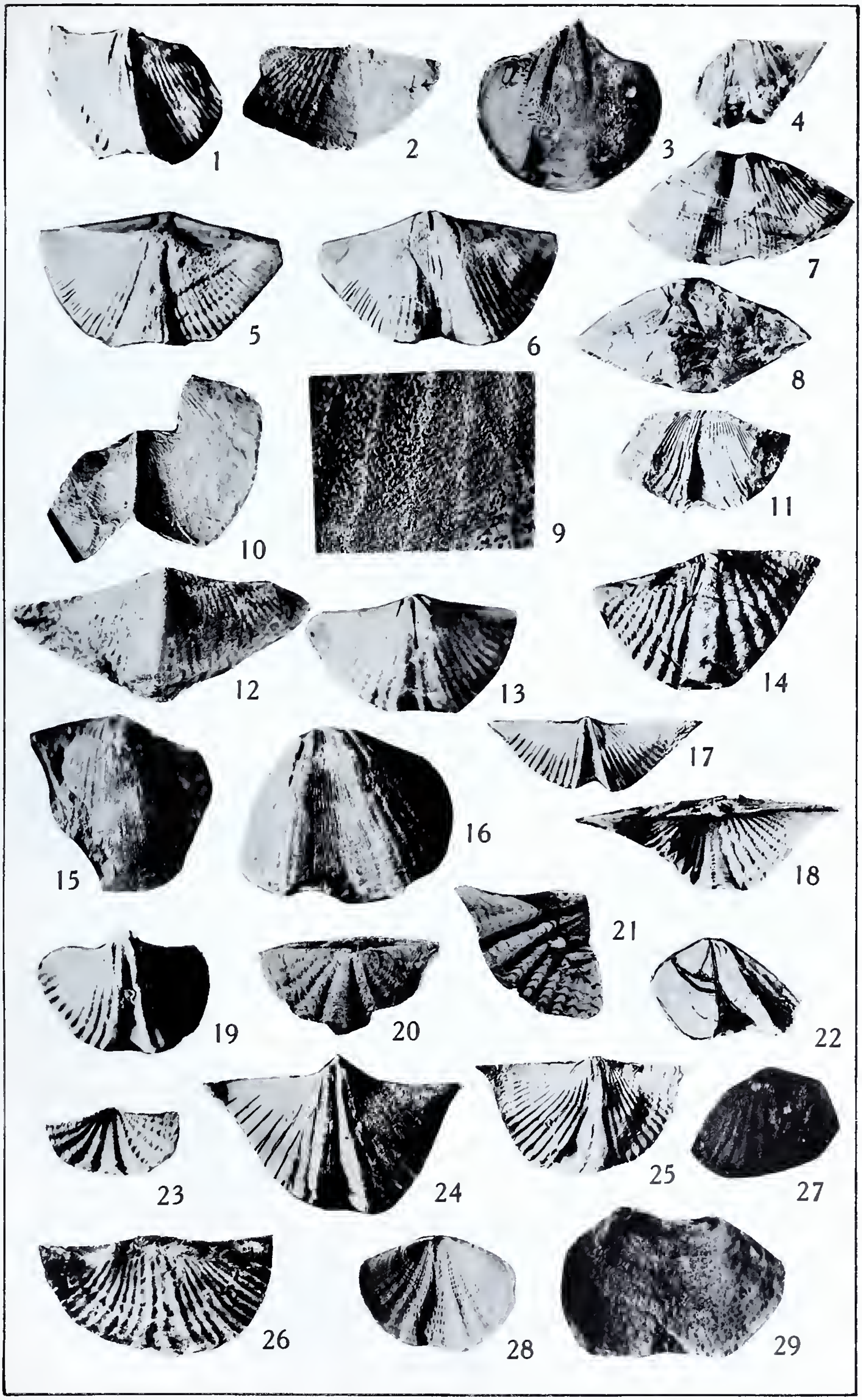
25. "*S.*" *tullius* Hall, dorsal valve, exterior x 2, topmost Mahantango shale, South Danville, Northumberland County.

26. "*S.*" *williamsi* (?) Hall and Clarke, dorsal valve, interior x 1½, Canadaway, Franklindale, Bradford County.

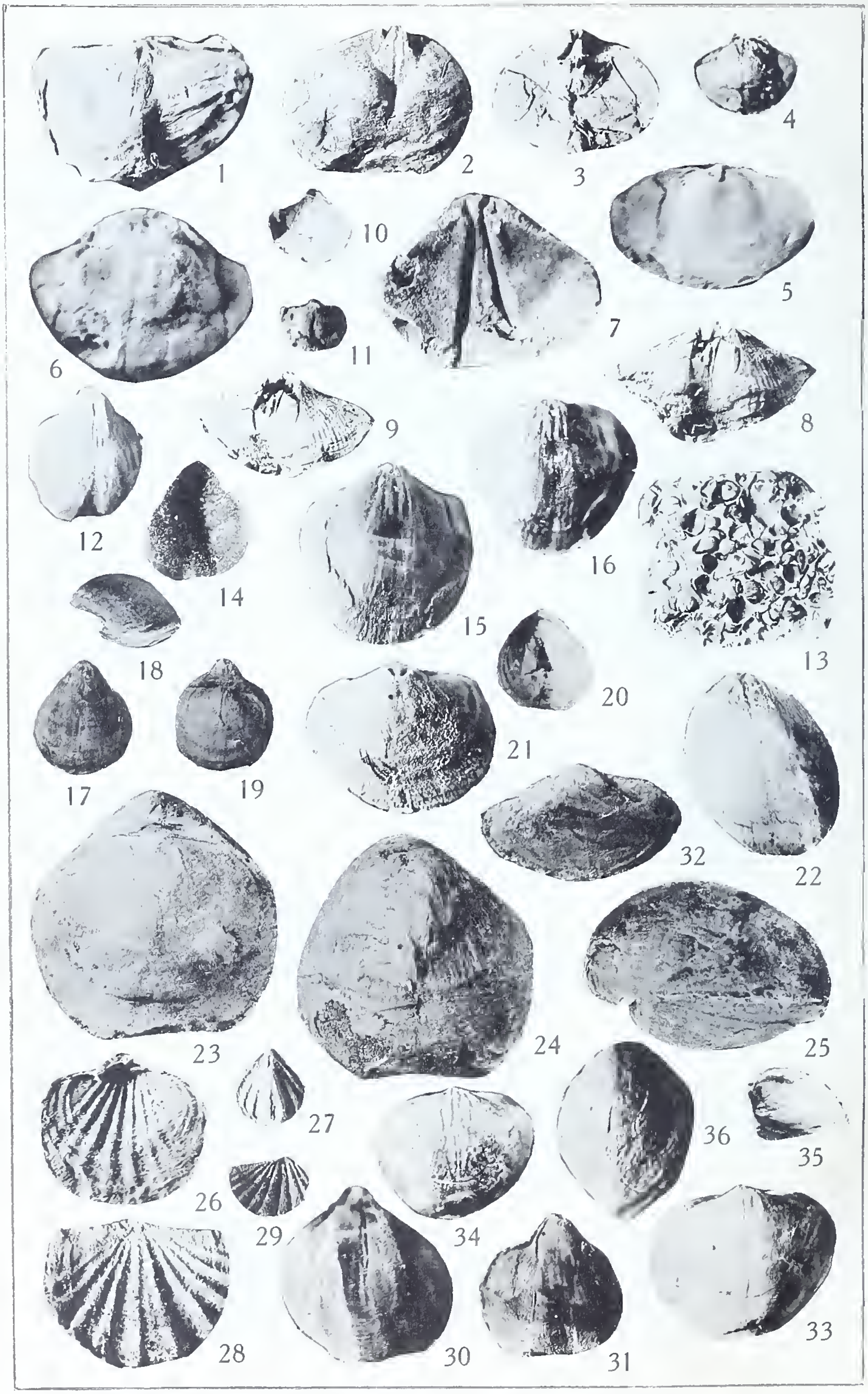
27. "*S.*" *macrothyris* (?) Hall, fragment of ventral valve x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)

28. *Elytha fimbriata* (Conrad), dorsal valve, exterior x 1, Mahantango formation, 4 miles south of New Bloomfield, Perry County.

29. *E. prœmatura* Hall, ventral valve (?) fragment x 2, "Chemung", east of Uniontown, Fayette County.



MIDDLE AND UPPER DEVONIAN BRACHIOPODA



MIDDLE AND UPPER DEVONIAN BRACHIOPODA

PLATE 22

Middle and Upper Devonian

BRACHIOPODA

1. *Reticularia lævis* (Hall), dorsal valve, internal cast x ½, Losh Run shale, 3 miles west of Chulasky, Northumberland County.
2. *R. lævis* (Hall), ventral valve, internal cast x ½, Losh Run shale, 3 miles west of Chulasky, Northumberland County.
3. *R. lævis* (Hall) dorsal valve, internal cast, bearing *Cladopora humilis*, x ½, Losh Run, shale, Juniata Valley, Perry County.
4. *Martinia subumbona* (Hall), dorsal valve, internal cast x 1, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
5. *M. subumbona* (Hall), dorsal valve, internal cast x 2, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
6. *M. subumbona* (Hall), ventral valve, internal cast x 2, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
7. *Syringothyris texta* (Hall), posterior aspect x 1, post-Chemung, Johnsonburg, Elk County.
8. *S. texta* (Hall), ventral valve, internal cast x ½, post-Chemung, Johnsonburg, Elk County.
9. *S. texta* (Hall), ventral valve, internal cast x ½, post-Chemung, Johnsonburg, Elk County.
10. *Ambocœlia nana* Grabau, ventral valve, internal cast x 2, Marcellus shale, quarry at Stroudsburg, Monroe County.
11. *A. nana* Grabau, ventral valve, internal cast x 2, Marcellus shale, quarry at Stroudsburg, Monroe County.
12. *A. umbonata* (Conrad), ventral valve, internal cast x 2, basal Chemung, Bedford, Bedford County.
13. *A. umbonata* (Conrad), mass of shells commonly referred to as *A. "gregaria"*, basal Chemung, Bedford County.
14. *A. umbonata* (Conrad), ventral valve, exterior x 2, basal Chemung, Bedford, Bedford County.
15. *A. præumbona* Hall, ventral valve, internal cast x 2, Mahantango formation, Barnetts Mill, Perry County.
16. *A. præumbona* Hall, ventral valve, internal cast x 2, Barnetts Mill, Perry County.
17. *Echinocœlia ambocœlioides* Cooper and Williams, ventral valve x 1, massive Tully limestone, Dunning Creek Valley, Bedford County. (Photograph by G. A. Cooper.)
18. *E. ambocœlioides* Cooper and Williams, laterial view x 1, massive Tully limestone, Dunning Creek Valley, Bedford County. (Photograph by G. A. Cooper.)
19. *E. ambocœliodes* Cooper and Williams, dorsal valve x 1, massive Tully limestone, Dunning Creek Valley, Bedford County. (Photograph by G. A. Cooper.)
20. *Charionella ovata* J. S. Williams, dorsal valve, exterior x 1, massive Tully limestone, Curtin, Centre County. (Photograph by G. A. Cooper.)
21. *Nucleospira concinna* Hall, dorsal valve, internal cast x 2, Mahantango formation, east-central Carbon County.

22. *N. concinna* Hall, ventral valve, internal cast x 2, Mahantango formation, east-central Carbon County.

23. *Emanuella pennsylvanica* Willard, dorsal valve, exterior x 2, massive Tully limestone, south-central Pennsylvania. (Photograph by G. A. Cooper.) Type.

24. *E. pennsylvanica* Willard, ventral valve, exterior x 2, massive Tully limestone, south-central Pennsylvania. (Photograph by G. A. Cooper.) Type.

25. *E. pennsylvanica* Willard, lateral aspect x 2, massive Tully limestone south-central Pennsylvania. (Photograph by G. A. Cooper.) Type.

26. *Anoplotheca acutiplicata* (Conrad), ventral valve, interior x 1½, Needmore shale, Schellsburg, Bedford County.

27. *A. camilla* (Hall), ventral valve x 1, exterior, Mahantango formation, Barnetts Mill, Perry County.

28. *Vitulina pustulosa* Hall, ventral valve, exterior x 2, top of Mahantango formation, South Danville, Northumberland County.

29. *V. pustulosa* Hall, ventral valve, exterior x 1, Barnetts Mill, Perry County.

30. *Athyris angelica* Hall, dorsal valve, internal cast x 1, Canadaway, East Charleston, Tioga County.

31. *A. angelica* Hall, ventral valve, internal cast x 1, Canadaway, East Charleston, Tioga County.

32. *A. cora* Hall, ventral valve, exterior x 1, New Milford formation, Drinkers Creek Valley, Susquehanna County.

33. *A spiriferoides* (Eaton), ventral valve, internal cast x 1, Mahantango formation, 1 mile west of Deer Lake, Schuylkill County.

34. *A. spiriferoides* (Eaton), ventral valve, internal cast x 1, Mahantango formation, South Danville, Northumberland County.

35. *Meristella nasuta* (Conrad), ventral valve, lateral aspect x 1, Mahantango formation, Mahantango Creek Valley, Snyder County.

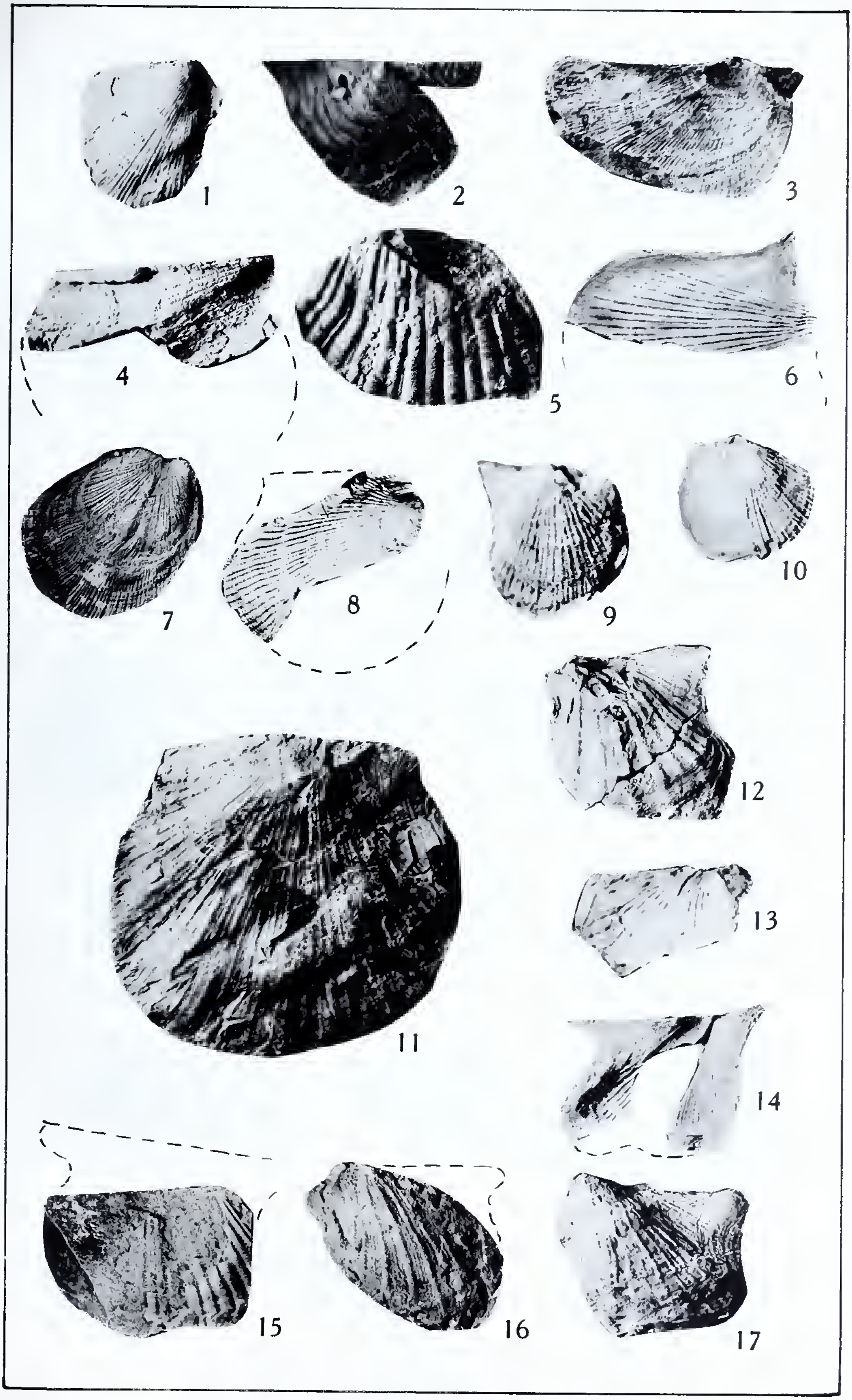
36. *M. nasuta* (Conrad), ventral valve, exterior, x 2, Mahantango formation, Mahantango Creek Valley, Snyder County.

PLATE 23

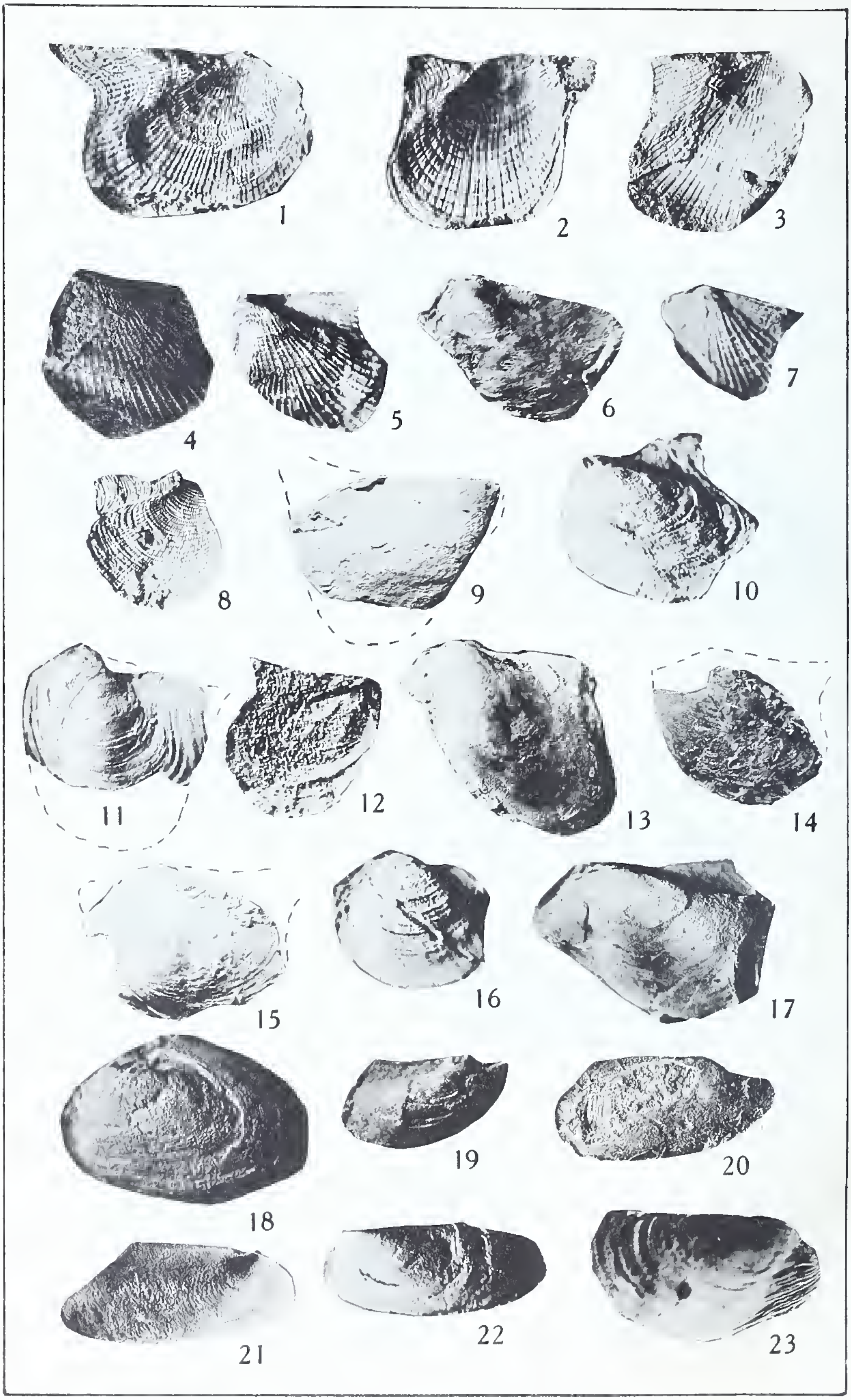
Middle and Upper Devonian

PELECYPODA

1. *Aviculopecten exactus* Hall, right valve x 2/3, Mahantango formation, Richfield, Juniata County.
2. *A. invalidus* Hall, left valve x 3, Marcellus shale, 1.5 miles north of Stroudsburg, Monroe County.
3. *A. princeps* (Conrad), left valve x ½, Mahantango formation, South Danville, Northumberland County.
4. *Lyriopecten interradius* (?) Hall, fragment, left valve x 1, Mahantango formation, McCoysville, Juniata County.
5. *L. magnificus* (?) Hall, fragment, x 1, "Chemung," Cowanesque Valley, Tioga County.
6. *L. priamus* (?) Hall, fragment, x 1, Chemung, Charleston, Tioga County.
7. *L. anomiæformis* (Hall), left valve x 1, Chemung, Pine Creek, Lycoming County.
8. *Pterinopecten crenicostatus* Hall, right valve x 1, Trimmers Rock, south of Montebello, Perry County.
9. *P. undosus* Hall, left valve x 1½, Mahantango formation, Board Run, Perry County.
10. *P. vetumnus* Hall, right valve x 1½, Mahantango formation, 4 miles south of New Bloomfield, Perry County.
11. *Pterinea chemungensis* (Conrad), left valve x 2/3, Trimmers Rock sandstone, Meiserville, Snyder County.
12. *P. dispanda* Hall, left valve x 1/3, "Chemung", one-half mile west of Jackson Summit, Tioga County.
13. *P. interstrialis* Hall, left valve x ½, Chemung, Bedford, Bedford County.
14. *P. consimilis* Hall, left valve x ½, Trimmers Rock sandstone, Newport, Perry County.
15. *P. prora* (2) Hall, fragment x 1, Trimmers Rock sandstone, Trimmers Rock, Perry County.
16. *P. flabellum* (Conrad), left valve x ½, Mahantango formation, Peru Mills, Juniata County.
17. *P. nodocosta* Clarke and Swartz, left valve x ½, Trimmers Rock sandstone, Meiserville, Snyder County.



MIDDLE AND UPPER DEVONIAN PELECYPODA



MIDDLE AND UPPER DEVONIAN PELECYPODA

PLATE 24

Middle and Upper Devonian

PELECYPODA

1. *Pterinea reprobra*, left valve x 1½, Trimmers Rock sandstone south of Montebello, Perry County.
2. *Actinopteria boydi* (Conrad), left valve x 2, Montebello sandstone, Green Point, Lebanon County.
3. *A. decussata* Hall, left valve x 2, Montebello sandstone, Green Point, Lebanon County.
4. *A. delta* Hall, left valve x 1½, Chemung, Oak Run, Lycoming County.
5. *A. epsilon* Hall, left valve x 1, Trimmers Rock sandstone, north of Kings Mill, Perry County.
6. *Actinodesma erectum* (?) (Conrad), left valve x 2/3, Trimmers Rock sandstone, northwest of Suedsburg, Schuylkill County.
7. *Actinopteria muricata* Hall, left valve x 2, Marcellus shale, Pennsylvania R. R. east of Schuylkill Haven, Schuylkill County.
8. *A subdecussata* Hall, left valve x ½, Mahantango formation, north of Marshalls Creek, Monroe County.
9. *Glyptodesma erectum* (?) Conrad, right valve x 2/3, Centerfield coral reef, north of Stroudsburg, Monroe County.
10. *Liopteria conradi* Hall, left valve x 1½, Trimmers Rock sandstone, 4 miles north of Milford, Pike County.
11. *L. bigsbyi* Hall, left valve x 1½, Trimmers Rock sandstone, Winfield, Union County.
12. *L. lævis* Hall, left valve x 3, Marcellus shale, Winfield, Union County.
13. *L. linguiformis* Hall, left valve x 1, Trimmers Rock sandstone, Pine Creek Valley, Lycoming County.
14. *L. marylandica* (?) Clarke and Swartz, fragment x 1, Chemung, Bedford, Bedford County.
15. *L. lepidum* (?) Hall, fragment x 1, "Chemung", Sweetbriar Church, Tioga County.
16. *L. sayi* Hall, left valve x 2½, Needmore shale, Pine Creek Valley, Lycoming County.
17. *Leptodesma creon* Hall, left valve x 2, "Chemung," Bear Creek, Tioga County.
18. *L. curvatum* Hall, left valve x 1½, "Chemung", Cowanesque Valley, Tioga County.
19. *L. becki* Hall, right valve x 2, Canadaway?, Franklindale, Bradford County.
20. *L. elongatum* Clarke and Swartz, right valve x 1½, Trimmers Rock sandstone, Winfield, Union County.
21. *L. jason* Hall, left valve x 2, Canadaway, south of Galeton, Potter County.
22. *L. medon* Hall, left valve x 1, Chemung, Warrens Mill, Somerset County.
23. *L. lesleyi* Hall, left valve x 1½, "Chemung" on Erie R. R. near Tioga, Tioga County.

PLATE 25

Middle and Upper Devonian

PELECYPODA

1. *Leptodesma lichas* Hall, right valve x 1, Trimmers Rock sandstone, Bartonville, Monroe County.
2. *L. longispinum* Hall, left valve x 2, Canadaway, south of Galeton, Potter County.
3. *L. multiplex* (?) Clarke, right valve x 2, Harrell shale (?), Mahantango Creek, Snyder County.
4. *L. naviforme* Hall, right valve x 2, Chemung, west of Newry, Blair County.
5. *L. rogersi* Hall, right valve x 2, "Chemung," Bear Creek, Tioga County.
6. *L. sociale* Hall, left valve x 4, Canadaway, Franklindale, Bradford County.
7. *L. sociale* Hall, left valve x 2, Canadaway, Franklindale, Bradford County.
8. *L. sociale* Hall, right valve x 2, Canadaway, Franklindale, Bradford County.
9. *L. orcus* Hall, left valve x 2, Canadaway, Franklindale, Bradford County.
10. *L. aliforme* (?) Hall, left valve x 1, Trimmers Rock sandstone, Oak Run, Lycoming County.
11. *L. orodes* (?) Hall, right valve x 2, Chemung (?) north of Shamokin Dam, Snyder County.
12. *Posidonia mesacostalis* (Williams), right valve x 4, Harrell shale, Saltillo, Huntingdon County.
13. *Kochia ungulia* Clarke, left (?) valve x 2, Harrell shale, 5 miles west of Duncannon, Perry County.
14. *Loxopteria corrugata* Clarke, left valve x 3, Harrell shale, Tatesville, Bedford County.
15. *Ectodesma birostratum* Hall, right valve x 1, Trimmers Rock sandstone, south of Sulphur Springs, Perry County.
16. *Mytilarca oviformis* (Conrad), right valve x 1, "Chemung," Bear Creek Valley, Tioga County.
17. *M. symplex* Hall, right valve x ½, "Chemung," Charleston Creek Valley, Tioga County.
18. *Modiomorpha alta* Hall, left valve x 2½, Marcellus (?), south of Dalmatia, Northumberland County.
19. *M. concentrica* Hall, fragment x ¾, Mahantango formation, Board Run, Perry County.
20. *M. mytiloides* Hall, right valve x ½, Trimmers Rock sandstone, Wilson Run, Northumberland County.
21. *M. subalata* Hall, left valve x ¾, New Milford sandstone, Starrucca Creek Valley, Susquehanna County.
22. *M. arcuata* Hall, right valve x ¾, New Milford sandstone, Starrucca Creek Valley, Susquehanna County.

23. *M. tioga* Hall, left valve x 3/4, Trimmers Rock sandstone, Analomink, Monroe County.

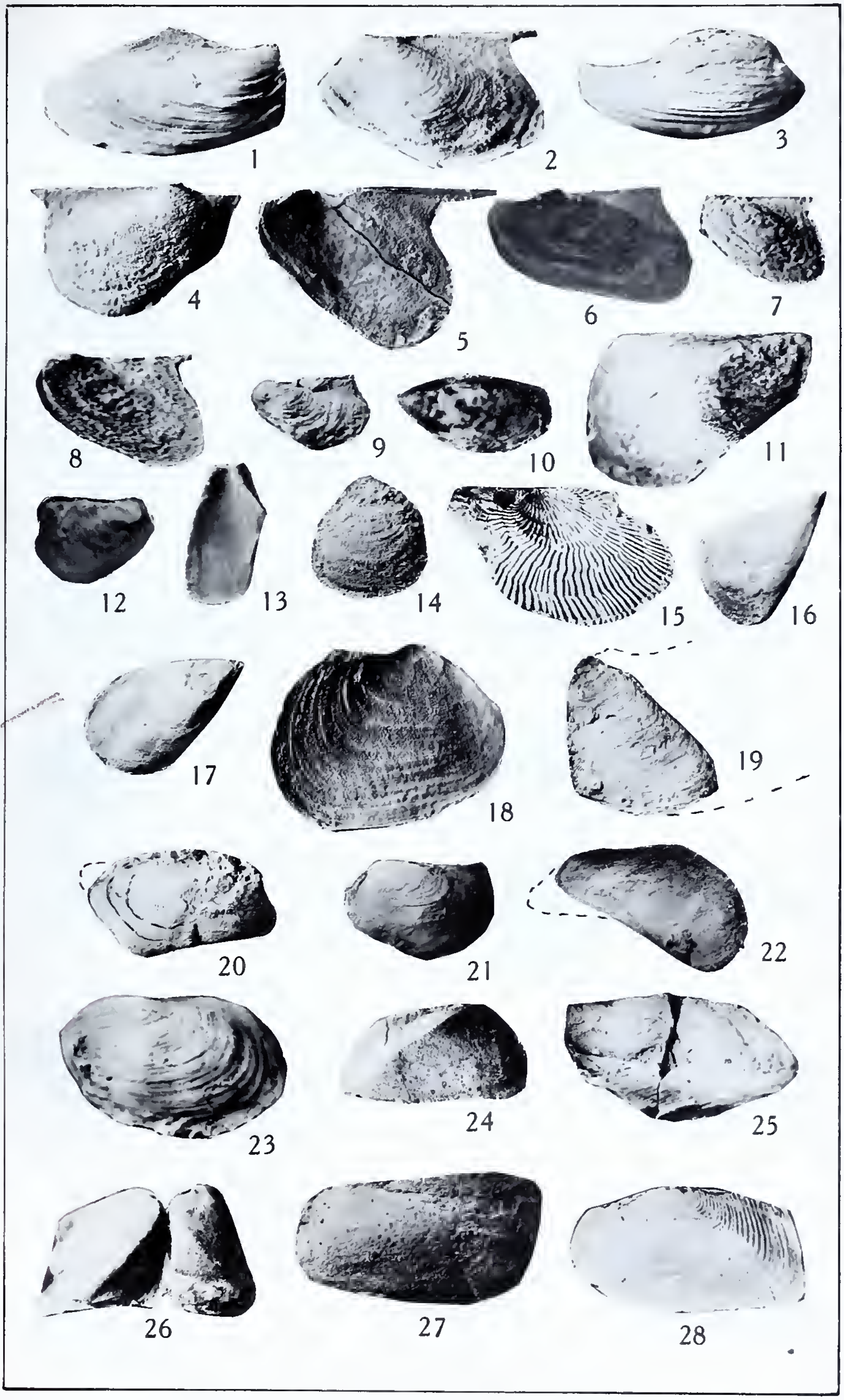
24. *Goniophora glaucus* Hall, right valve x ½, Trimmers Rock sandstone, Meiserville, Snyder County.

25. *G. hamiltonensis* Hall, fragment x ½, Mahantango formation, Reading R.R. north of Auburn, Schuylkill County.

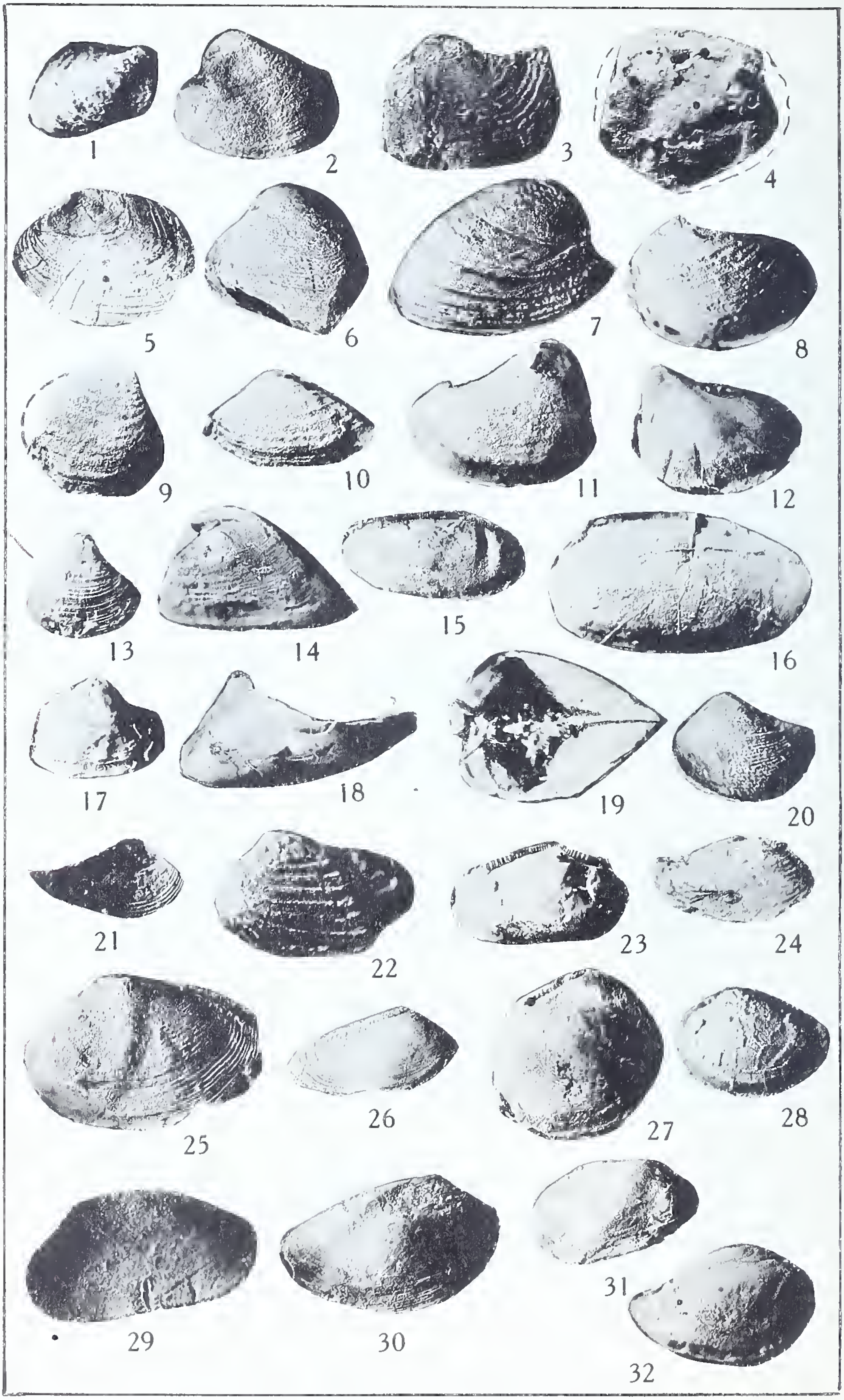
26. *G. rugosa* (Conrad), left and right valves x ½, Trimmers Rock sandstone, Meiserville, Snyder County.

27. *G. chemungensis* (?) (Vanuxem), left valve x 1½, "Chemung", north branch Thornbottom Creek, Tioga County.

28. *Cypricardella bellistriata* (Conrad), right valve x 1½, Mahantango formation, Richfield, Juniata County.



MIDDLE AND UPPER DEVONIAN PELECYPODA



MIDDLE AND UPPER DEVONIAN PELECYPODA

PLATE 26

Middle and Upper Devonian

PELECYPODA

1. *Cypricardella indenta* (Conrad), right valve x 2, Mahantango formation, Harrisonville, Fulton County.
2. *C. marylandica* (?) Clarke and Swartz, left valve x 1, Chemung, Warren's Mill, Somerset.
3. *C. nitidula* Clarke and Swartz, left valve x 2, Mahantango formation, Mahantango Creek Valley, Snyder County.
4. *C. cumberlandiæ* (?) Clarke and Swartz, fragment x ½, Trimmers Rock sandstone, Harrisonville, Fulton County.
5. *C. tenuistriata* (Hall), right valve x ½, Mahantango formation, Eichelbergertown, Bedford County.
6. *Nucula bellistriata* (Conrad), left valve x 1½, Mahantango formation, Huntingdon, Huntingdon County.
7. *N. bellistriata* (Conrad), right valve x 2, Mahantango formation, Dimmsville, Juniata County.
8. *N. corbuliformis* Hall, left valve x 1½, Mahantango formation, 8 miles north of Mausdale, Montour County.
9. *N. globularis* Hall, right valve x 1, Canadaway, south of Galeton, Potter County.
10. *N. lirata* (Conrad), left valve x 2, Mahantango formation, north of Marshalls Creek, Monroe County.
11. *N. lirata* (Conrad), right valve, internal cast x 1, Mahantango formaton, south of Junata River at Huntingdon, Huntingdon County.
12. *N. randalli* Hall, left valve, internal cast x 2, Mahantango formation, Mahantango Creek Valley, Snyder County.
13. *N. varicosa* Hall, right valve x 1, Mahantango formation, south of Juniata River at Huntingdon, Huntingdon County.
14. *Nuculities cuneiformis* Conrad, left valve x 1½, Mahantango formation, west of Seven Stars, Juniata County.
15. *N. oblongata* Conrad, right valve, internal cast x 1, Mahantango formation, Dimmsville, Juniata County.
16. *N. oblongata* Conrad, left valve, internal cast x 1, Mahantango formation, Dimmsville, Juniata County.
17. *N. triqueter* Conrad, left valve x 1, Mahantango formation, Cove Creek Valley, Fulton County.
18. *Leda diversa* Hall, left valve, internal cast x 2, Mahantango formation, Dimmsville, Juniata County.
19. *L. diversa* Hall, superior aspect, internal cast x 2, Mahantango formation, Dimmsville, Juniata County.
20. *L. obscura* Hall, left valve x 2, Trimmers Rock sandstone, Analomink, Monroe County.
21. *L. rostellata* (Conrad), left valve x 2, Mahantango formation, Dimmsville, Juniata County.
22. *Palæoneilo emarginata* (Conrad), left valve x 2, Mahantango formation, South Danville, Northumberland County.

23. *P. brevis* Hall, right valve, internal cast x 1½, Trimmers Rock sandstone, Juniata Valley, east Perry County.

24. *P. angusta* Hall, right valve x 1, Chemung, Blues Gap, Bedford County.

25. *P. fecunda* Hall, left valve x 2, Mahantango formation, South Danville, Northumberland County.

26. *P. filosa* (Conrad), right valve x 2, Chemung, Oak Run, Lycoming County.

27. *P. maxima* (Conrad), right valve, internal cast x 1½, Mahantango formation, Reading R. R. north of Auburn, Schuylkill County.

28. *P. plana* Hall, left valve, internal cast x 2, Mahantango formation, south of Juniata River at Huntingdon, Huntingdon County.

29. *P. plana* Hall, left valve x 2, Mahantango formation, Manns Choice, Bedford County.

30. *P. tenuistriata* Hall, right valve x 1, Mahantango formation, Huntingdon, Huntingdon County.

31. *Nyassa arguta* Hall, right valve x 1, Marcellus shale, quarry at Stroudsburg, Monroe County.

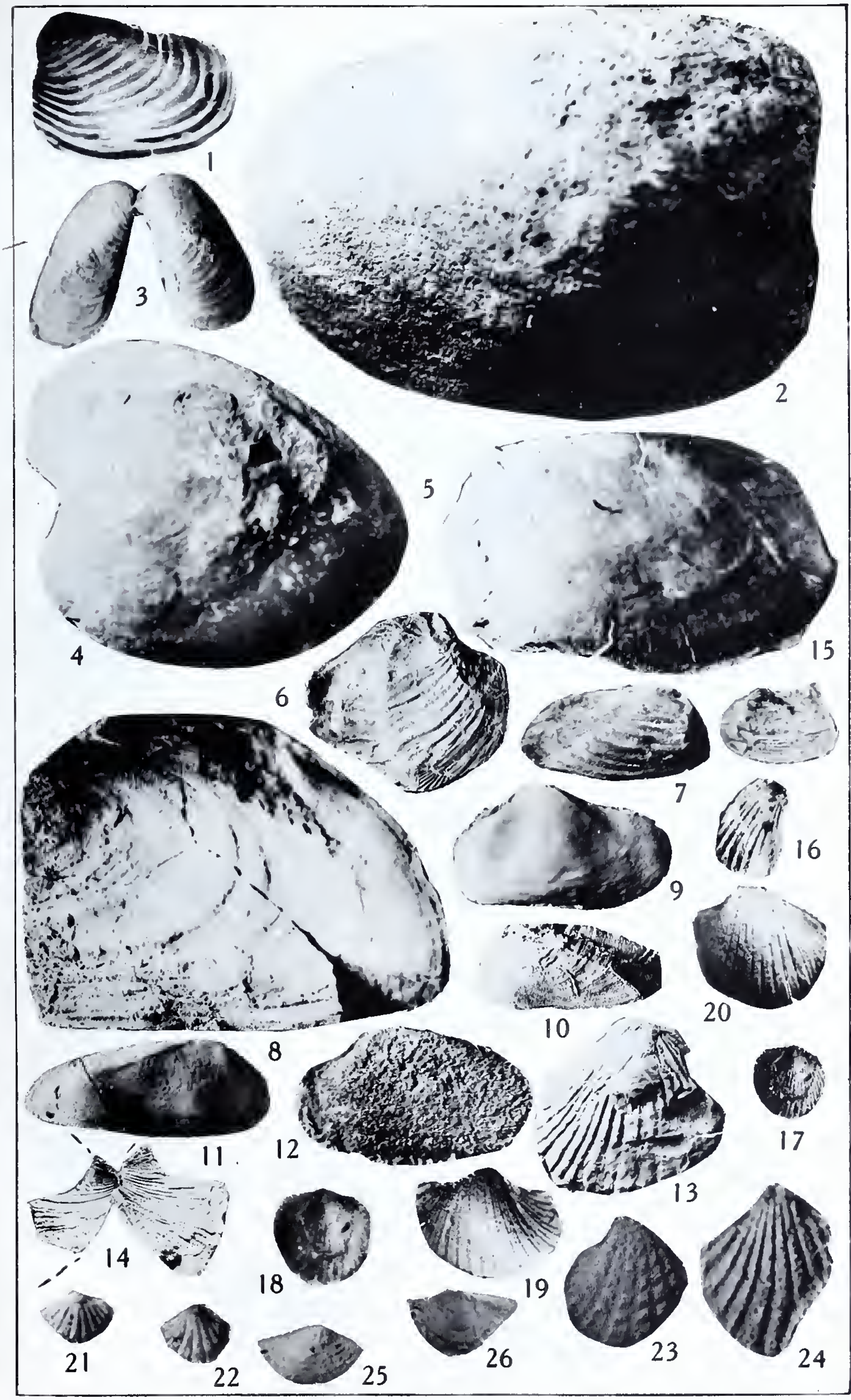
32. *N. subalata* Hall, right valve x 2, Trimmers Rock sandstone, north of Milford, Pike County.

PLATE 27

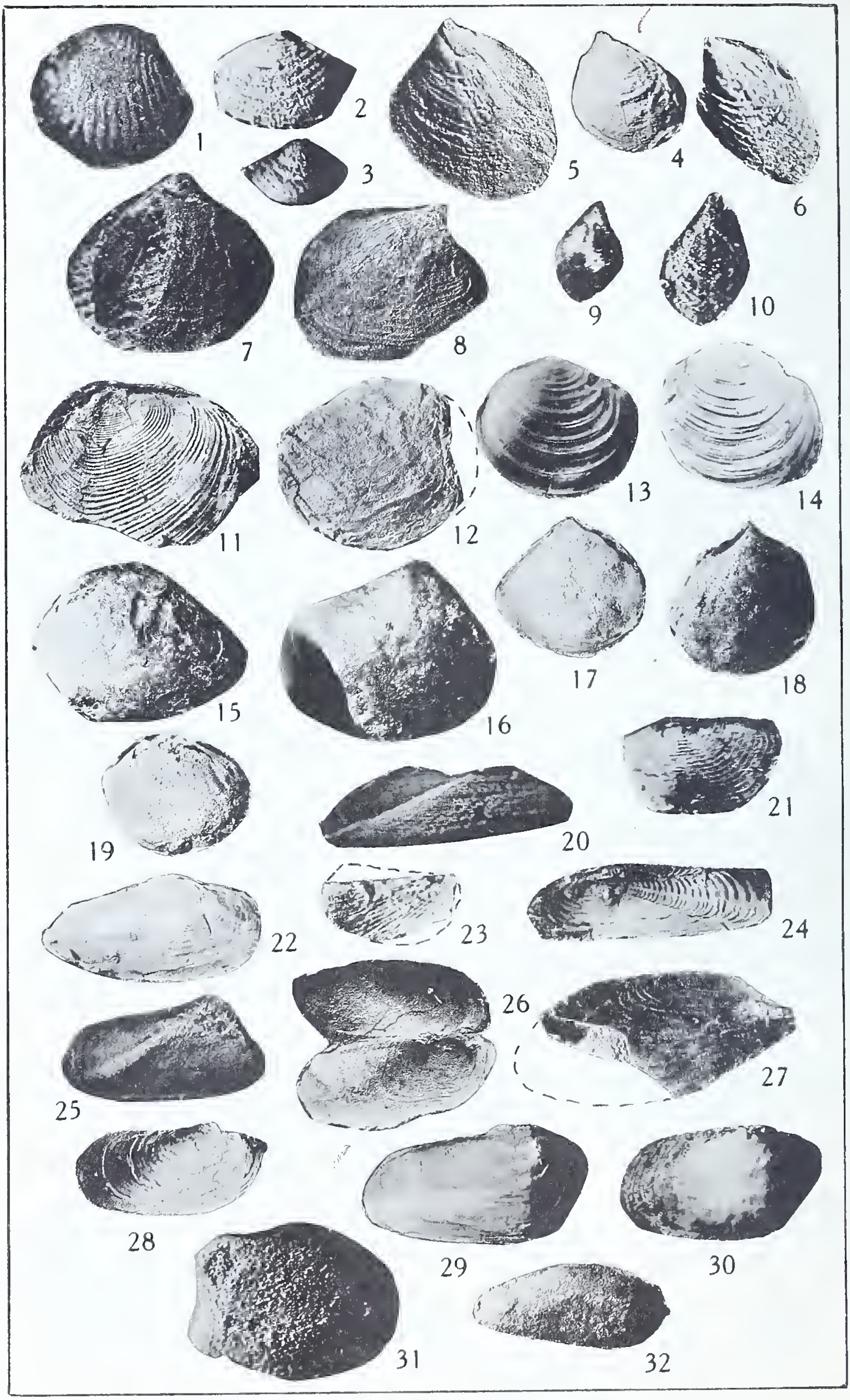
Middle and Upper Devonian

PELECYPODA

1. *Grammysia arcuata* (Conrad), right valve x ¾, Mahantango formation, McCoysville, Juniata County.
2. *G. circularis* Hall, right valve x 1, Mahantango formation, Fiddlers Run, Northumberland County.
3. *G. communis* Hall, right and left valves x 1, Trimmers Rock sandstone, Meiserville, Juniata County.
4. *G. elliptica* Hall, left valve x 2/3, Canadaway, Franklindale, Bradford County.
5. *G. magna* Hall, left valve x ¾, Mahantango formation, Reading R. R. north of Auburn, Schuylkill County.
6. *G. bisulcata* (Conrad), left valve x ½, Trimmers Rock sandstone, McMichael's Creek Valley, Monroe County.
7. *G. subcircularis* Hall, right valve x 1, Trimmers Rock sandstone, Newport, Perry County.
8. *G. obsoleta* Hall, right valve x 1, Mahantango formation, Black Valley Gap, Bedford County.
9. *G. subnasuta* Hall, left valve x 1, Canadaway, South of Galeton, Potter County.
10. *Sphenotus contractus* Hall, left valve x 1, Chemung, Port Matilda, Centre County.
11. *S. clavus* (Conrad), right valve x 1. "Chemung", Victoria, Fayette County.
12. *Spathella typica* Hall, left valve x 2, "Chemung", Victoria, Fayette County.
13. *Panenka costata* Hall, right valve x ½, Marcellus shale, quarry at Stroudsburg, Monroe County.
14. *P. hero* Hall, fragmentary right and left valves x ½, Marcellus shale, quarry at Stroudsburg, Monroe County.
15. *Ontaria suborbicularis* (Hall), right valve x 2, Harrell shale, Mahantango Creek Valley, Snyder County.
16. *Buchiola conversa* Clarke, left valve x 4, Harrell (?) shale, south of Little Wapwallopen Creek, Luzerne County.
17. *B. livoniæ* Clarke, right valve x 3, Harrell shale, Bedford, Bedford County.
18. *B. livoniæ* Clarke, right valve x 4, Harrell shale, Bedford, Bedford County.
19. *B. mariæ* Clarke and Swartz, left valve x 3, Harrell shale, Tatesville, Bedford County.
20. *B. mariæ* Clarke and Swartz, left valve x 3, Harrell shale, Tatesville, Bedford County.
21. *B. retrostriata* (von Buch), left valve x 3, Harrell shale, Chaneysville, Bedford County.
22. *B. retrostriata* (von Buch), left valve x 3, Harrell shale, Chaneysville, Bedford County.
23. *B. susquehannica* Willard, left valve x 2, shaly top of Tully, Larrys Creek, Lycoming County. Type.
24. *Præcardium vetustum* Hall, left valve x 4, Harrell shale, Larrys Creek, Lycoming County.
25. *Paracardium delicatum* Clarke, right valve x 4, Harrell shale, Chaneysville, Bedford County.
26. *P. delicatum* Clarke, right valve x 4, Harrell shale, Chaneysville, Bedford County.



MIDDLE AND UPPER DEVONIAN PELECYPODA



MIDDLE AND UPPER DEVONIAN PELECYPODA

PLATE 28

Middle and Upper Devonian

PELECYPODA

1. *Paracardium doris* Hall, left valve x 4, Harrell shale, Tatesville, Bedford County.
2. *Lunulicardium cymbula* Clarke and Swartz, right valve x 4, Harrell shale, Lock Haven, Clinton County.
3. *L. encrinitum* Clarke, right valve x 4, Harrell shale, Saltillo, Huntingdon County.
4. *L. absegmen* Clarke, left valve x 2, Harrell shale, Bedford, Bedford County.
5. *Pterochænia fragilis* (Hall), left valve x 3, Harrell shale, Tatesville, Bedford County.
6. *P. fragilis* (Hall), left valve x 3, Harrell shale, Tatesville, Bedford County.
7. *P. fragilis* var. *orbicularis* Clarke, right valve x 3, Harrell shale, Saltillo, Huntingdon County.
8. *P. sinuosa* Clarke, right valve x 2½, Harrell shale, Saltillo, Huntingdon County.
9. *P. cashaquæ* Clarke, right valve x 2, Harrell shale, Saltillo, Huntingdon County.
10. *P. cashaquæ* Clarke, right valve x 3, Harrell shale, Saltillo, Huntingdon County.
11. *Paracyclas elliptica* Hall, left valve x 1, Mahantango formation, Deer Lake, Schuylkill County.
12. *P. tenuis* (?) Hall, left valve, fragment x 1, Mahantango formation, Chaneysville, Bedford County.
13. *P. lirata* (Conrad), left valve x 2, Mahantango formation, southwest of Schuylkill Haven, Schuylkill County.
14. *P. lirata* (Conrad), left valve x 1, Mahantango formation, Green Point, Lebanon County.
15. *Schizodus appressus* (Conrad), left valve x 1/3, Trimmers Rock sandstone, Pine Creek Valley, Lycoming County.
16. *S. oblatus* Hall, right valve, fragment x 1, New Milford sandstone, Drinker Creek Valley, Susquehanna County.
17. *S. trigonalis* Clarke and Swartz, left valve x 2/3, Chemung, east of Chaneysville, Bedford County.
18. *S. rhombeus* Hall, right valve x 1, Kings Mill sandstone, Roseglen, Perry County.
19. *S. rhombeus* Hall, left valve x 1, King's Mill sandstone, Roseglen, Perry County.
20. *Prothyris lanceolata* Hall, right valve x 2½, Mahantango formation, Dimmsville, Juniata County.
21. *Solemya ventrosla* (?). Meek, left valve x 2, Mahantango formation (Moscow), Barnetts Mill, Perry County.
22. *Tellinopsis subemarginata* Conrad, right valve x 1, Mahantango formation, McCoysvilie, Juniata County.

23. *Phthonia nodicostata* (?) Hall, left valve, fragment x 1½, Trimmers Rock sandstone, 3 miles north of Milford, Pike County.

24. *Orthonota undulata* Conrad, left valve x 2/3, Mahantango formation, Board Run, Perry County.

25. *O. parvula* Hall, right valve x 3, Mahantango formation, Selinsgrove Junction. Northumberland County.

26. *Palæanatina typus* Hall, right and left valves x 1½, "Chemung", Yarnell Brook Valley, Tioga County.

27. *Glossites lingualis* Hall, left valve, fragment x ¾, "Chemung", east of Charleston, Tioga County.

28. *G. rudicula* Hall, left valve x 1½, "Chemung", Cowanesque Valley, Tioga County.

29. *Sanguinolites subtruncata* Hall, right valve x 2, Canadaway, south of Galeton, Potter County.

30. *S. undulatus* Hall, left valve x 2, "Chemung", Ohiopyle, Fayette County.

31. *Modiella pygmiæ* (Conrad), left valve x 2½, Trimmers Rock sandstone, Swatara Hill, Schuylkill County.

32. *Amnigenia catskillensis* (Vanuxem), left valve x ½ 'Chemung", Ohiopyle, Fayette County.

PLATE 29

Middle and Upper Devonian

GASTROPODA

1. *Macrochilus hamiltoniae* Hall, lateral view, internal cast x 2, Mahantango formation, Cove Creek Valley, Fulton County.

2. *Cyrtolites mitella* Hall, lateral view x 2, Mahantango formation, Harrisonville, Fulton County.

3. *C. mitella* Hall, dorsal view x 2, Mahantango formation, Huntingdon, Huntingdon County.

4. *C. pileolus* Hall, dorsal view, fragment x 1, Mahantango formation, Chaneysville, Bedford County.

5. *Bellerophon crenistria* Hall, dorsal view, fragment x 2, Mahantango formation, Eichelbergertown, Bedford County.

6. *B. leda* Hall, dorsal view x 1½, Mahantango formation, Harrisonville, Fulton County.

7. *B. lyra* Hall, dorsal view, mold x 2, Onondaga black shale, Pennsylvania R. R., Newton Hamilton, Mifflin County.

8. *B. nactoides* Clarke and Swartz, lateral view x 1½, Trimmers Rock sandstone, Juniata Valley, east side, Perry County.

9. *B. patulus* Hall, ventral view x 1, Mahantango formation, Schellsburg, Bedford County.

10. *B. triradiatus* Hall, dorsal view x 1, "Chemung," Bear Creek Valley, Tioga County.

11. *Bucheanopsis maera* (Conrad), lateral view, fragment x 2, Trimmers Rock sandstone, Harrisonville, Fulton County.

12. *Ectomaria ecclesiae* Clarke and Swartz, lateral view, fragmentary mold x 3, Losh Run shale, west of Liverpool, Perry County.

13. *Pleurotomaria genundewa* Clarke, upper surface, mold x 3, Harrell shale, Middleburg, Snyder County.

14. *P. capillaria* Conrad, lateral view x 4, massive Tully limestone, Sproul, Blair County. (Photograph by G. A. Cooper.)

15. *P. capillaria* Conrad, lateral view, squeeze x 1, Mahantango formation, Huntingdon, Huntingdon County.

16. *P. capillaria* Conrad, lateral view, cast x 1, Mahantango formation, Huntingdon, Huntingdon County.

17. *P. filitexta* Hall, upper surface, cast x 1, Mahantango formation, Lehighton, Carbon County.

18. *P. itys* Conrad, lateral view, cast x 1, Mahantango formation, 4.8 miles north of Mausdale, Montour County.

19. *P. lucina* (?) Hall, lateral view, mold x 2, Onondaga black shale, Pennsylvania R. R., Newton Hamilton, Mifflin County.

20. *P. sulcomarginata* Conrad, lateral view, cast x 1, Mahantango formation, south of Juniata River at Huntingdon, Huntingdon County.

21. *P. sulcomarginata* Conrad, upper surface, mold x 1, Mahantango formation, Richfield, Juniata County.

22. *Murchisonia micula* Hall, lateral view, cast x 4, Mahantango formation, Eichelbergertown, Bedford County.

23. *Straparollus hecale* Hall, lower surface x 1, "Chemung," Erie R. R. near Tioga, Tioga County.

24. *Trochonema libratum* (Hall), lateral view, fragment x 2½, Trimmers Rock sandstone, north of Mausdale, Montour County.

25. *Anomophalus minutissima* Clarke, lateral view, mold x 5, Marcellus shale, 1½ miles north of Stroudsburg, Monroe County.

26. *Diaphorostoma lineatum* (Conrad), upper view x 1, Hazard paint ore, Palmerton, Carbon County.

27. *D. lineatum* (?) (Conrad), fragment x 1, Trimmers Rock sandstone, Juniata Valley east side, Perry County.

28. *D. lineatum* (Conrad), dorsal view x 1, Trimmers Rock sandstone, Juniata Valley east side, Perry County.

29. *D. turbinatum* (Hall), lateral view x 1, Mahantango formation, north of Neola, Monroe County.

30. *Platyceras auriculatum* Hall, lateral view, cast x 1, Mahantango formation (Skaneateles), Brodhead Creek Valley, Monroe County.

31. *P. conicum* Hall, dorsal view, cast x 2, Mahantango formation, Deer Lake, Schuylkill County.

32. *P. erectum* Hall, lateral view, cast x 1, Mahantango formation, Barnetts Mill, Perry County.

33. *P. prosseri* (?) Clarke and Swartz, lateral view, cast x 1, Trimmers Rock sandstone, south of Rupert, Columbia County.

34. *Platystoma cuamphaloides* (?) Hall, lateral view, fragment x 1, Mahantango formation, Richfield, Juniata County.

35. *Loxonema hamiltoniae* Hall, lateral view, squeeze x 1½, Mahantango, north of Dalmatia, Northumberland County.

36. *L. bellona* Hall, lateral view, cast x 1, Mahantango formation. Deer Lake, Schuylkill County.

37. *L. multiplicata* (?) Clarke. lateral view, fragment x 1, Harrell shale, Chaneysville, Bedford County.

38. *L. multiplicata* Clarke, lateral view x 4, Harrell shale, Chaneysville, Bedford County.

39. *L. terebra* Hall, lateral view, mold x 3, Harrell shale, Middleburg, Snyder County.

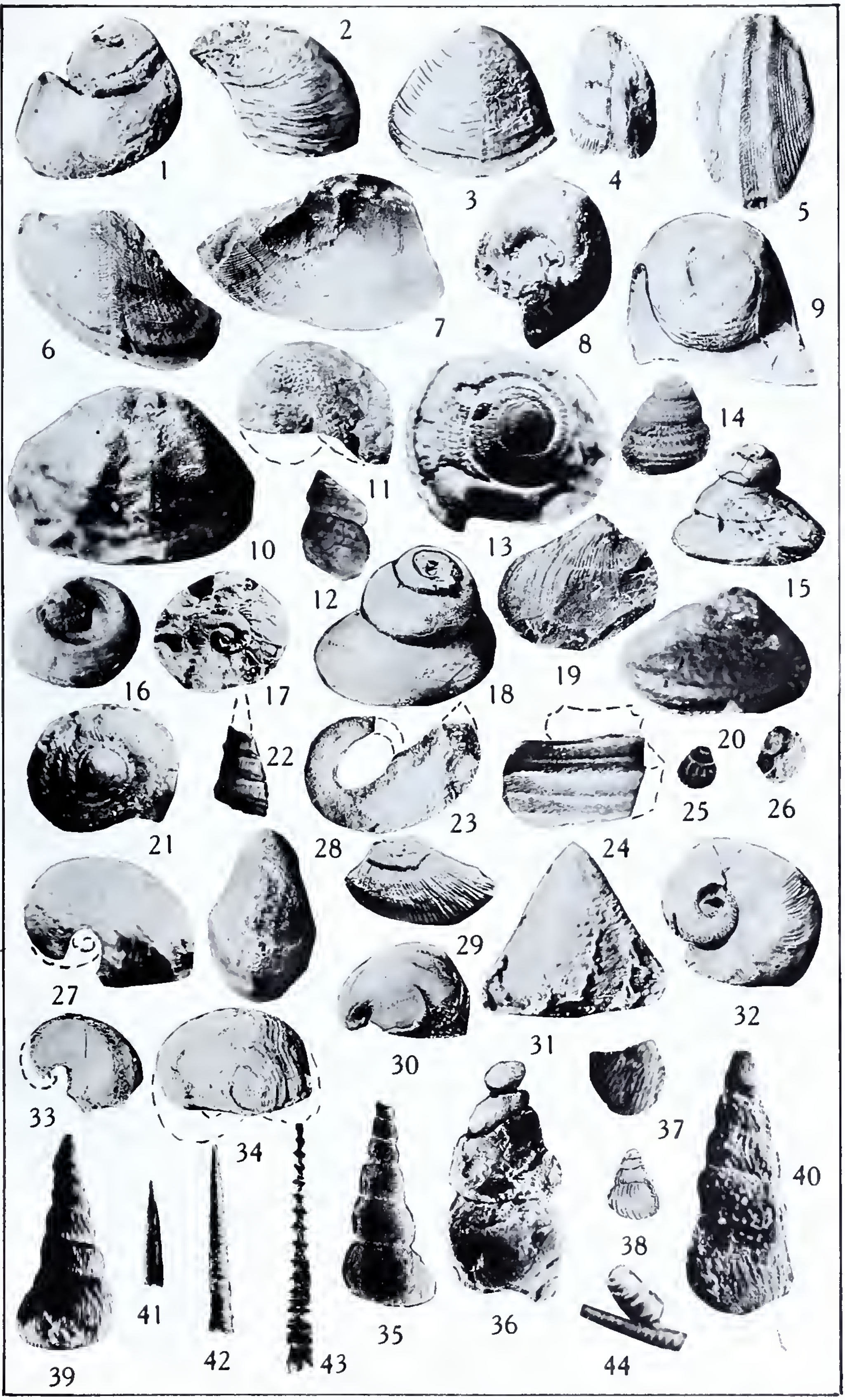
40. *L. noe* Clarke, lateral view, mold x 3, Harrell shale, Middleburg, Snyder County.

41. *Styliolina fissurella* (Hall), Marcellus shale, enlarged, Black Valley Gap, Bedford County.

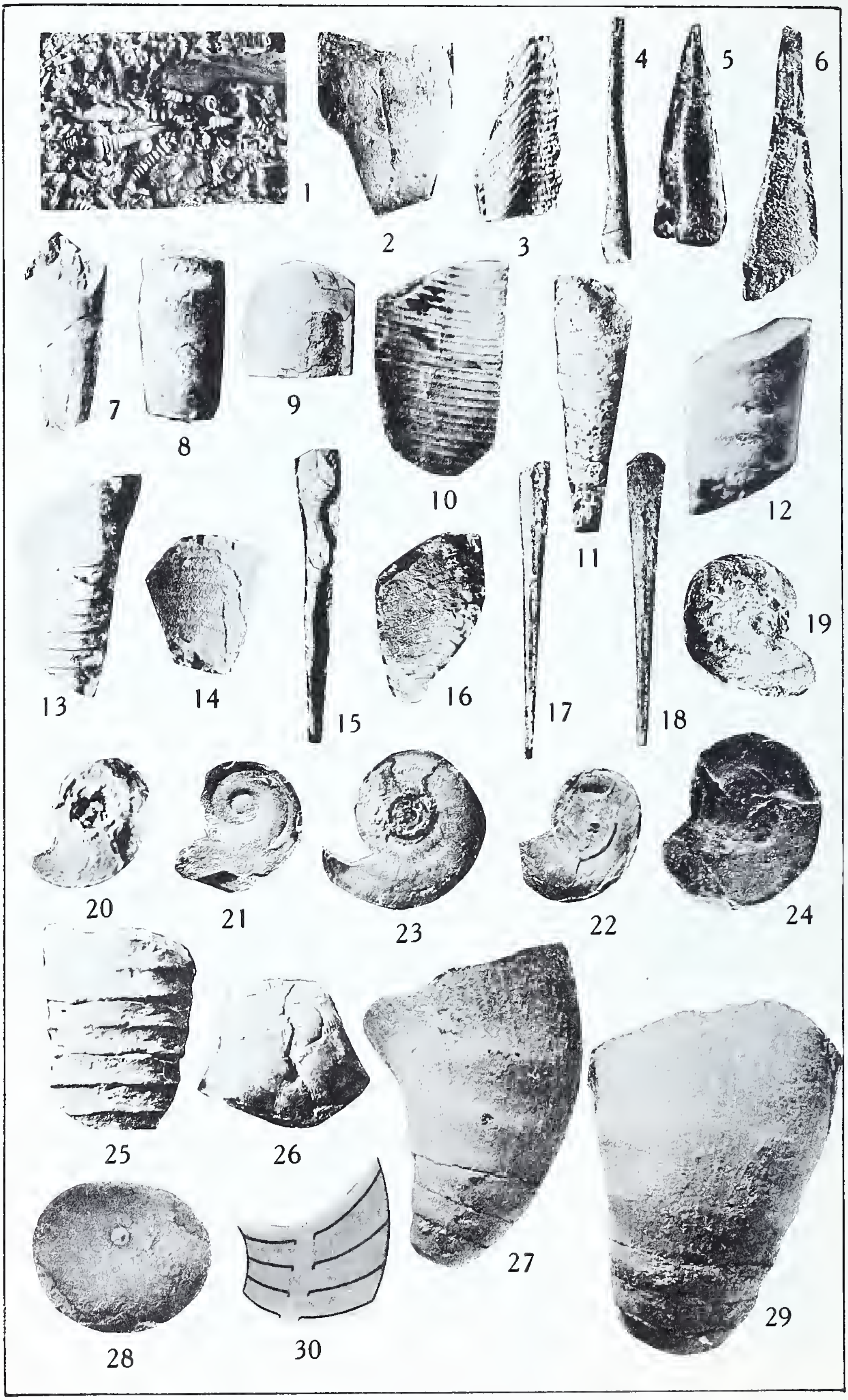
42. *Tentaculites bellulus* Hall, Montebello sandstone, enlarged, Drumgold, Perry County.

43. *T. bellulus* Hall, Mahantango formation, enlarged, Cove Creek Valley, Fulton County.

44. *T. spiculus* Hall, Trimmers Rock sandstone, enlarged, Lehigh River Valley, Carbon County.



MIDDLE AND UPPER DEVONIAN GASTROPODA



MIDDLE AND UPPER DEVONIAN GASTROPODA AND CEPHALOPODA

PLATE 30

Middle and Upper Devonian

GASTROPODA AND CEPHALOPODA

GASTROPODA

1. *Tentaculites spiculus* Hall, coquinite x 2, Trimmers Rock sandstone, Juniata Valley east, Perry County.

2. *Conularia undulata* Conrad, x 1½, Onondaga black shale, Pennsylvania R. R., Newton Hamilton, Mifflin County.

3. *C.* sp., x 3, Trimmers Rock sandstone, Meiserville, Snyder County.

4. *Coleolus tenuicinctus* Hall, x 1½, Trimmers Rock sandstone, Fort Littleton, Fulton County.

5. *Hyolithus aclis* Hall, x 2, Mahantango formation, Oak Run, Lycoming County.

6. *H. neapolis* Clarke, x 3, Harrell shale, south of Newry, Blair County.

CEPHALOPODA

7. *Orthoceras aulax* Hall, x ⅔, Trimmers Rock sandstone, Roddy, Perry County.

8. *O. constrictum* Vanuxem, x 1, Mahantango formation, South Danville, Northumberland County.

9. *O. exile* (?) Hall, x 1, Mahantango formation, Reading R. R., north of Auburn, Schuylkill County.

10. *O. filosum* Clarke, x 2, Harrell shale, Tatesville, Bedford County.

11. *O. subulatum* Hall, x 1, Marcellus shale, Blue Spring, Juniata County.

12. *O. telamon* Hall, x 1, Mahantango formation, Huntingdon, Huntingdon County.

13. *Gomphoceras nasutum* Hall, x 1½, Chemung, Blues Gap, Bedford County.

14. *G. pingue* Hall, x 1½, Mahantango formation, Websters Mill, Fulton County.

15. *Bactrites clavus* Hall, x ½, Mahantango formation, Dimmsville, Juniata County.

16. *B. gracilior* Clarke, x 2, Harrell shale, Saltillo, Huntingdon County.

17. *B. aciculum* (Hall), x 1, Harrell shale, Tatesville, Bedford County.

18. *B. aciculum* (Hall), x 1, Harrell shale, Tatesville, Bedford County.

19. *Agoniatites expansus* (Vanuxem), x 1, Onondaga black shale, Pennsylvania R. R., Newton Hamilton, Mifflin County.

20. *Paradisceras discoideum* (Hall), x 1, Marcellus shale, Jersey Shore, Lycoming County.

21. *Manticoceras fasciculatum* Clarke, x 1, Harrell shale, Lycoming Creek Valley, Lycoming County.

22. *M. patersoni* (Hall), x 2, Harrell shale, Unionville, Centre County.

23. *Probeloceras lutheri* Clarke, x 1, Harrell shale, Tatesville, Bedford County.

24. *Cyrtoclymenia neapolitana* Clarke, x 3, Harrell shale, Saltillo, Huntingdon County.

25. *Spyroceras crotalum* (?) (Hall), x ⅔, "Chemung," east of Uniontown, Fayette County.

26. *Nephritoceras bucinum* Hall, x ¾, Marcellus shale, quarry at Stroudsburg, Monroe County.

27. *Bacopleuroceras incipiens* J. S. Williams, lateral view x 2, massive Tully limestone, Curtin, Centre County. (Photograph by A. K. Miller.)

28. *B. incipiens* J. S. Williams, septal view x 2, massive Tully limestone, Curtin, Centre County. (Photograph by A. K. Miller.)

29. *B. incipiens* J. S. Williams, ventral valve x 2, massive Tully limestone, Curtin, Centre County. (Photograph by A. K. Miller.)

30. *B. incipiens* J. S. Williams, longitudinal section x 2, massive Tully limestone, Curtin, Centre County. (Drawn by A. K. Miller.)

PLATE 31

Middle and Upper Devonian

ARTHROPODA

1. *Cyphaspis minuscula* Hall, x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
2. *Conolichas eriopsis* (Hall), glabella x 2, Hazard paint ore, Palmerton, Carbon County.
3. *Acidaspis callicera* Hall and Clarke, free cheek with spines x 2, Hazard paint ore, Palmerton, Carbon County.
4. *Homalonotus dekayi* (Green), cephalon, fragmentary x ½, Mahantango formation (limestone lense), Manns Choice, Bedford County.
5. *H. dekayi* (Green), thorax x ½, Mahantango formation, Tyrone, Blair County.
6. *H. dekayi* (Green), pygidium x ½, Mahantango formation, north of Adamsdale, Schuylkill County.
7. *Phacops rana* (Green), x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
8. *P. rana* (Green), enrolled individual x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
9. *P. rana* (Green), enrolled individual x 1½, Mahantango formation, Friedensburg, Schuylkill County.
10. *P. rana* (Green), cephalon x 1, Mahantango formation, Friedensburg, Schuylkill County.
11. *P. cristata* Hall, thorax and pygidium, showing medial spine bases x 1, Hazard paint ore, Palmerton, Carbon County.
12. *P. cristata* var. *pipa* Hall and Clarke, cephalon x 1, Hazard paint ore, Palmerton, Carbon County.
13. *P. cristata* var. *pipa* Hall and Clarke, pygidium x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
14. *P. cristata* var. *pipa* Hall and Clarke, lateral view, enrolled individual showing genial spine x 1, Hazard paint ore, Palmerton, Carbon County.
15. *P. cristata* var. *pipa* Hall and Clarke, cephalon x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
16. *Odontocephalus aegeria* Hall, pygidium x 1, Hazard paint ore, Palmerton, Carbon County. (Photograph by L. Whitcomb.)
17. *Greenops boothi* (Green), pygidium x 1½, Mahantango formation, Barnetts Mill, Perry County.
18. *G. boothi* (Green), pygidium x 1, Mahantango formation, Brodhead Creek Valley, Monroe County.
19. *G. marylandica* (?) (Prosser), pygidium x 1½, Mahantango formation, 4 miles south of New Bloomfield, Perry County.
20. *G. bedfordensis* Willard, pygidium x 1, massive Tully limestone, Imler, Bedford County. (Photograph by G. A. Cooper.) Syntype.
21. *G. bedfordensis* Willard, pygidium x 1, massive Tully limestone, Schellsburg, Bedford County. (Photograph by G. A. Cooper.) Syntype.

22. *Proetus rowi* Hall and Clarke, fragmentary cephalon and thorax, x 2, Mahantango formation, Barnetts Mill, Perry County.

23. *Phaethonides gemmaeus* Hall and Clarke, pygidium x 2, Hazard paint ore, Palmerton, Carbon County.

24. *Ceratocaris beecheri* Clarke, x 2, Trimmers Rock sandstone, 1.5 miles southeast of Wapwallopen, Luzerne County.

25. *Echinocaris multinodosa* Whitfield, x 1½, Trimmers Rock sandstone, Analomink, Monroe County.

26. *E. punctata* Hall, x ⅔, Mahantango formation, Peru Mills, Juniata County.

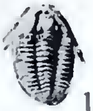
27. *E. sublaevis* Whitfield, x 1, Canadaway, south of Hollenback, Bradford County.

28. *Rhinocaris capsella* Hall and Clarke, x 2, Trimmers Rock sandstone, ¼ mile west of Snyders, Schuylkill County.

29. *R. columbina* Clarke, x 1½, Chemung, Mill Creek, Huntingdon County.

30. *Mesothyra oceani* Hall and Clarke, x 2, Trimmers Rock sandstone, Girtys Notch, Perry County.

31. *Stylonurus shaffneri* Willard, ambulateral appendage x ¾, Canadaway, south of Galeton, Potter County?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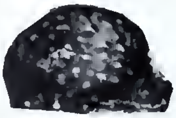
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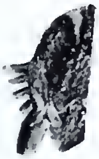
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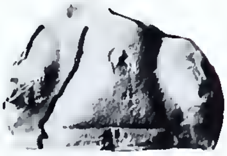
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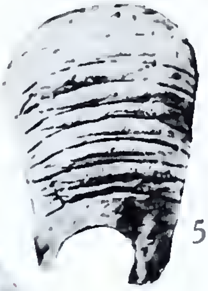
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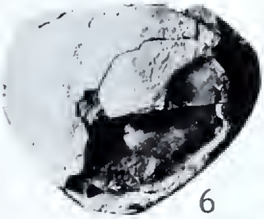
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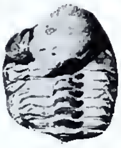
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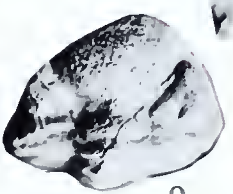
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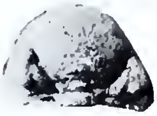
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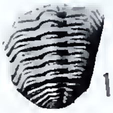
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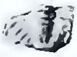
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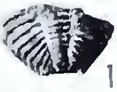
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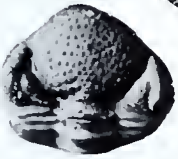
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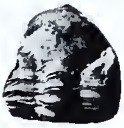
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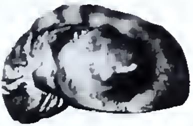
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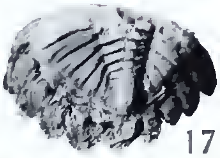
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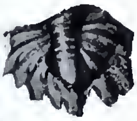
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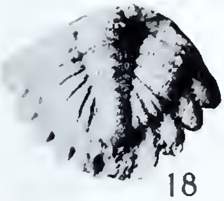
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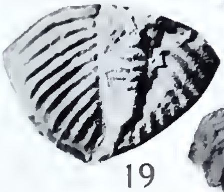
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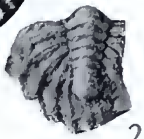
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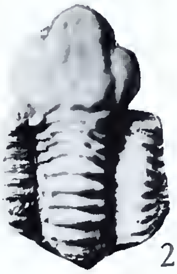
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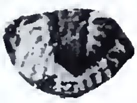
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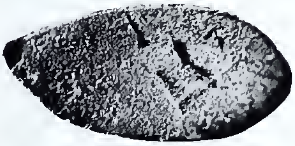
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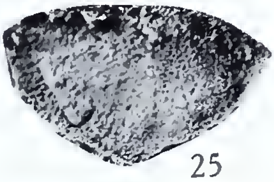
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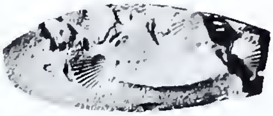
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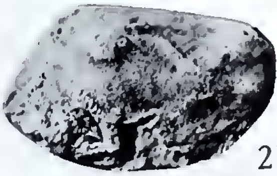
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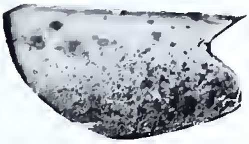
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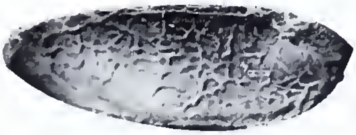
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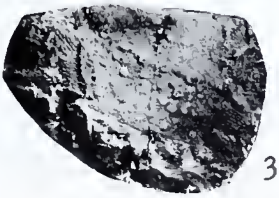
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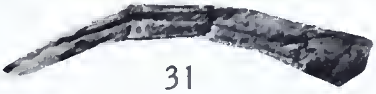
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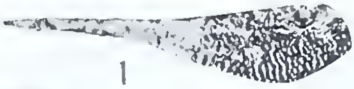
MIDDLE AND UPPER DEVONIAN ARTHROPODA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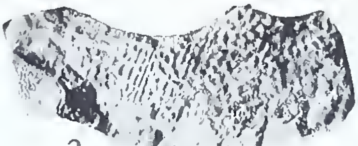
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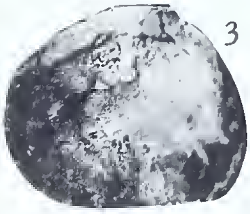
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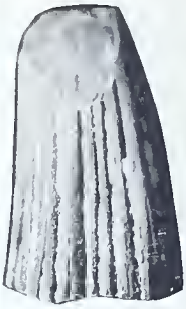
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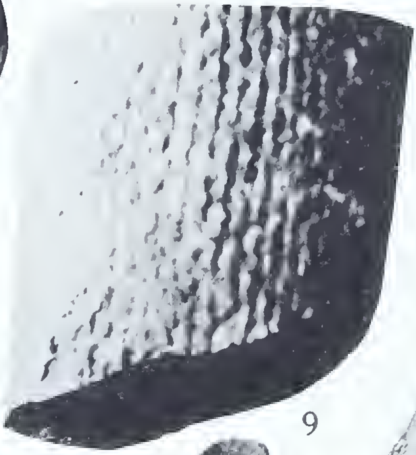
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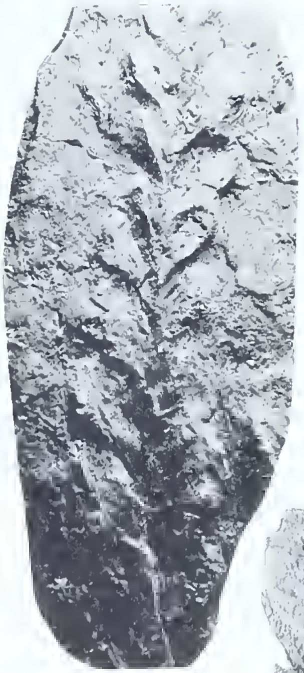
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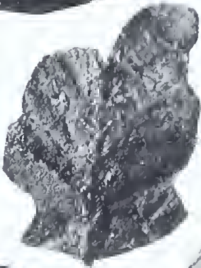
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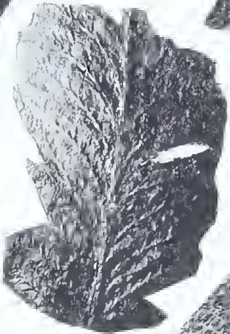
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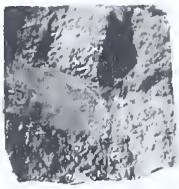
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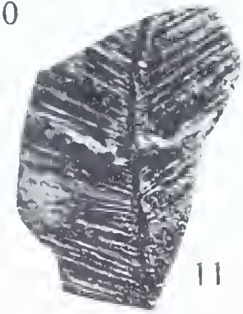
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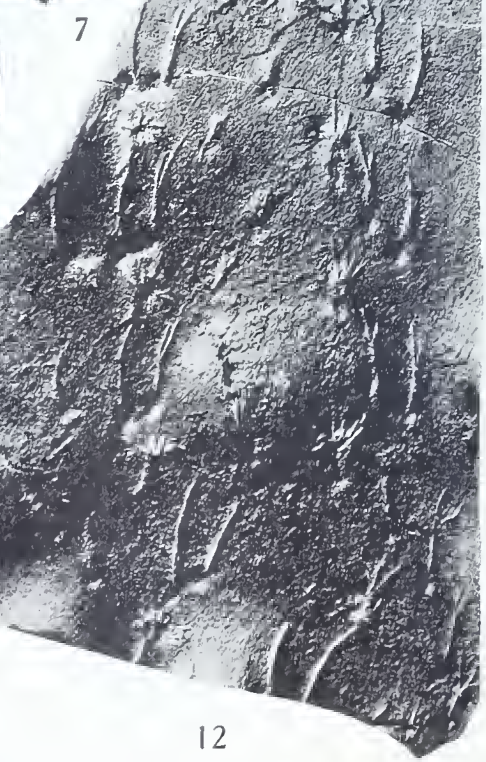
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UPPER DEVONIAN VERTEBRATA, PLANTAE, PROBLEMATICAL

PLATE 32

Middle and Upper Devonian

VERTEBRATA, PLANTAE, PROBLEMATICAL

VERTEBRATA

1. *Bothriolepus minor* Newberry, plate fragment x 1½, Cherry Ridge red beds (?), north of Hollenback, Bradford County.
2. *B. leseyi* Newberry, plate fragments x 1, Cherry Ridge (?) red beds, Mill Creek, Tioga County.
3. *Holoptychius* sp., scale x 1½, Canadaway, Lambs Creek, Tioga County.
4. *Apendulus priscus* Leidy, spine x 2, Conneaut (?), east of Smethport, McKean County.
5. Fish spine, undetermined, x ½, Trimmers Rock sandstone, Winfield, Union County.

PLANTAE

6. *Archaeopteris obtusus* (Lesquereux), x ½ Damascus (?) red beds, north of Ariel, Wayne County.
7. *A. obtusus* (Lesquereux), x ½, Damascus red beds, Susquehanna County.
8. *A. halliana* (?) Hall, x ½, Damascus red beds, Susquehanna County.
9. *Protolepidodendron* sp., stem x ⅔, Trimmers Rock sandstone, quarry at Newport, Perry County.
10. Woody fragments in Brallier shale, x 2, Juniata County.

PROBLEMATICAL

11. *Plumularia* sp., x 1½, Losh Run shale, Juniata Valley east, Perry County.
12. *Paramphibius tridactylus* Willard, trail x 1, Chemung, Starrucca Creek Valley, Susquehanna County. Paratype.

BIBLIOGRAPHY

In the following pages will be found a list of references. Most of these deal directly with the Devonian of Pennsylvania. However, titles have been included that are only indirectly germane in that they cover adjacent territory, particularly New York, New Jersey, Maryland and Ohio. Several of these are inserted for those who may possibly be interested in a particular phase of our Devonian as carried over into adjacent regions. Thus, several articles on the Devonian and Mississippian of Ohio have been mentioned. Also, numerous accounts of paleontology are listed. Of particular importance are those by James Hall and John M. Clarke of the New York Survey. These and certain of the New Jersey and Maryland references are introduced because of their bearing upon Chapter XI, Paleontology. A few general texts, chiefly of an historic nature, are also cited. Because of the character of the bibliography, some of the citations are not mentioned in the text of this bulletin. Where articles have been cited, it has been done by giving the bibliographic number in parentheses, sometimes, in specific instances, with the addition of page reference.

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